Electronic Paper Display preferred viewing distance and character size for different age groups

Hsin-Chieh Wu*

Department of Industrial Engineering and Management, Chaoyang University of Technology, No.168, Jifong East Road, Wufong District, Taichung, 41349, Taiwan, ROC

*E-mail: hcwul@cyut.edu.tw. Tel.: 886-4-2332-3000 ext.4537. Fax: 886-4-2374-2327.

引用此篇文獻時請註明出處:

Wu, H.C. (2011/9) Electronic paper display preferred viewing distance and character size for different age groups, Ergonomics, 54 (9), 806-814
Abstract

This study explores the preferred viewing distance and character size for an electronic paper display for three age groups. Proofreading speed and accuracy ratio were measured during Chinese proofreading tests using the preferred character size and minimum acceptable character size. Data analysis showed that the mean preferred viewing distance for young, middle-aged and older groups was 503, 455, and 444 mm, respectively. The mean preferred character size determined by young, middle-aged and older groups was 42.0, 50.0 and 55.2 min arc, respectively. The proofreading test results indicated that the older group proof-read significantly more slowly (1.25 word/sec) than the young (1.76 word/sec) and middle-aged groups (1.74 word/sec). Further, the participants proofread more correctly with their preferred character size (73.3%) than with their minimum acceptable character size (65.4%). This study provides valuable information for the design of Chinese text presentations for various age groups.

Keywords: office ergonomics; ageing; information displays; standards

Statement of Relevance

This study confirmed the preferred viewing distance and character size for E-paper display were influenced by age. The preferred Chinese character size for young, middle-aged, and older people was 42, 50, and 55 min arc, respectively. Therefore, the age factor should be considered for E-paper displays design and VDT guidelines.
1. Introduction

More electronic-books (e-books) have been published online owing to the popularity of computer networks and the requirement for mobile reading. With the increase in the number of e-books published, the sales of varied electronic paper (E-paper) displays have grown continuously in recent years. Among these technologies, E-paper made of cholesteric liquid crystal (Ch-LC) and electrophoretic electronic ink (E-ink) are two popular products in the market (Lee et al., 2008). The advantages of E-paper are lightweight, low power consumption and sunlight readability. Unlike conventional VDT (i.e. CRT and TFT-LCD), E-paper can be read using only ambient lighting conditions as a reading source. E-paper has no backlight (Lee et al., 2003; Lin et al., 2008). The display type effect on Chinese reading performance and visual fatigue has been studied (Wu et al., 2007). The Kolin E-paper display was found to produce significantly less visual fatigue than the portable computer and the PDA, although these three displays had similar reading performance (Wu et al., 2007). Consequently, the E-paper display can be considered a good reading device without producing great visual strain.

Viewing distance is an important factor affecting visual performance and visual fatigue. As we know, the eyes assume a vergence resting position, approximately corresponding to a distance of 1 m, without a fixation stimulus or in a dark visual field (Jaschinski-Kruza, 1991; Rosenfield, 1997). When the target is closer (less than 1 m), the extra-ocular muscles must exert stronger ocular force to turn the visual axes toward each other. This is considered the reason why people perceive visual fatigue near computer screens (Collins et al., 1975; Tyrrell and Leibowitz, 1990). Those who have a weak vergence system because of a smaller vergence gain tend to prefer viewing distances longer than 50 cm to avoid the visual fatigue induced by near screens (Jaschinski, 1998; Jainta and Jaschinski, 2002). Therefore, German DIN 66234...
(1981) suggested that the VDT viewing distance should be a minimum of 500 mm. Similarly, the Swedish ISO Proposal (1982) suggested that the VDT viewing distance should be between 500 and 700 mm. Ankrum (1996) investigated the optimal viewing distance for desktop monitors and recommended a minimum distance of 635 mm. Likewise, Hennings and Ye (1996) suggested about 600 mm VDT viewing distance.

Concerning the optic differences between E-paper displays and VDTs, Shieh and Lee (2007) investigated the preferred viewing distance for reading English text from two types of E-paper. Their experimental results showed that the preferred viewing distance for E-paper was similar to that of VDT at around 500 mm. Further, Wu and Chan (2006) found that the mean preferred viewing distance was 498 mm for reading Chinese text from a Kolin E-paper display. The above-mentioned studies were based on young adults, and therefore the viewing distance suggestion may not be suitable for older adults. A well-developed literature reports that problems with vision tend to appear in the early forties (Fozard, 1990). Further studies are required to understand the preferred viewing distance for E-paper for the people who are older than 40 years.

Lee et al. (2008) evaluated English alphabet search performance using the Kolin Ch-LC E-paper display and Sony E-ink E-paper display under character heights of 9.6, 15.1, 22.7, and 29.6 min arc. Their results showed that there was no significant difference in search performance between these two E-paper displays. The search speed increased as character size increased, up to 22.7 min arc. Thus, the recommended English character size should subtend a visual angle of about 22 min arc (Lee et al., 2008). Their suggestion is obviously smaller than that for the preferred Chinese character size of 43 min arc found in Wu and Chan’s study (2006). The difference in character size suggestion between these two studies can be attributed to two reasons. On one hand, there exist fundamental differences between Chinese characters and the English alphabet. Chinese characters usually have more strokes
than the alphabetical (Cai et al., 2001), a larger Chinese character size is required for good legibility. On the other hand, Wu and Chan’s study (2006) was based on subjective preference for reading Chinese articles. Lee, et al’s study (2008) relied mainly on alphabet search performance. Because these two research results were obtained from young adults, the preferred character sizes for E-paper displays for older adults are still unknown to date. Further studies are needed to investigate preferred character size for middle-aged and older adults.

The goal of this study was to find the preferred Chinese character size presented on electronic paper for young, middle-aged and older groups. The previous recommendations for character size were often expressed in terms of visual angle (Sanders and McCormick, 1993). This study also translated the preferred character height (mm) into the subtended visual angle (min of arc). The preferred character size is larger than the minimum acceptable character size and consequently has better legibility. However, the reading performance differences between character sizes are often not significantly apparent until the size difference becomes quite large (Mills and Weldom, 1987; Tinker, 1963). It is still unknown whether the preferred character size is large enough to result in significantly better reading performance than the minimum acceptable size. It is obvious that older readers will have worse reading performance than the young when both use the same size text. The question remains: Do older readers have the same or worse performance than the young when the elder reader has larger preferred character size? Do older readers prefer larger character size than younger people when using corrected lenses to read? An experimental study was conducted to solve these questions. Three hypotheses were examined in this study, as follows.

H1: Proof-reading speed and accuracy ratio are greater using the preferred character size compared to using the minimum acceptable character size.

H2: Proof-reading speed and accuracy ratio are different between age groups when all of the
participants read with their personal preferred character sizes.

H3: When the elderly wear far-sighted glasses to read, they prefer larger character size than the young.

2. Methods

2.1. Apparatus

The Kolin Ch-LC e-book Reader was used as the electronic paper display medium. The device had a 6.5-in diagonal screen that provided an active viewing area of 97 mm horizontally and 129 mm vertically. The dimensions of this Reader were 135 (wide) × 180 (high) × 17 (thickness) mm, and 290 g in weight. This e-book Reader had only monochrome display text. The background color was greenish blue rather than white. The measured maximum luminance contrast ratio \( \frac{L_{\text{background}}}{L_{\text{text}}} \) was 1.2, which was steady in all of the experimental trials. The pixel resolution was 480 horizontally and 640 vertically, and the center-to-center pixel spacing was 0.206 mm. The content on the screen could be easily controlled by pushing the previous and next paging buttons. The paging control was quite similar to turning the page in a conventional book. This study input 30 sample articles with different character sizes (12~41 points) into the e-book Reader for participants to select from. The actual height of the prepared characters ranged from 2.48 to 8.47 mm. The height and width of each Chinese character were almost the same.

2.2. Participants

Seventy-eight participants (39 males and 39 females) were recruited for this study. They were divided into three age groups (years): young (21–35 yrs), middle-aged (36–49 yrs) and older groups (50–70 yrs). Each group had 13 males and 13 females. Descriptive statistics for
the study sample are provided in table 1. The preferred viewing distance, minimum acceptable character size and preferred character size were measured in the preference test and are explained later. To be eligible for inclusion in this study, all participants had to be in good ocular health. All subjects were pre-tested for at least 0.8 visual acuity, with corrected lenses if needed. The visual acuity of each subject was tested using the Snellen visual acuity chart. Most elderly participants (88.5%) are far-sighted and most young participants (92.3%) are near-sighted, as shown in table 1. Because of near-sighted or far-sighted vision, most of the participants required corrected lenses during the proof-reading test. None of them had experience reading from the tested electronic paper display. Some younger participants (34.6%) had experience with PDA or small screen displays. However, middle-aged and elderly participants (7.7%) rarely had experience with PDA or small screen displays. The participants worked as college students, college staff, policemen, teachers, engineers, government personnel, attendants, workers, doctors, businessmen, retiree, and housewives. Prior to participating in this experiment; the study was explained in detail to all of the participants. They were then requested to fill out a written consent form to indicate their awareness of the experimental goals and their willingness to participate the study.

2.3. Protocol

2.3.1. Preference test

Each participant was informed that intensive visual tasks were not permitted in the one hour before the preference test. At first, the participant was seated in an adjustable chair that was used to produce the preferred posture while reading from the e-book Reader. The e-book Reader was supported by a small bookrack with an inclination angle of 45° from the table surface, as shown in figure 1. The initial character size on the screen was 23 point (4.75 x
4.75 mm), as referred to Wu et al.’s study (2007). Because character size can affect viewing distance, this study maintained a constant character size to determine the participants’ preferred viewing distance. The participant was asked to adjust the distance from the eyes to the screen centre according to their favorite viewing distance. After the preferred viewing distance was determined, a chin-support tripod was used to fix the participant’s head (figure 1). The viewing distance was kept at the personal preferred viewing distance in the following tests.

With the preferred viewing distance, the participants would carefully select two sizes of Chinese characters from the 30 sample articles in the e-book Reader. The two character sizes included the minimum acceptable character size and preferred character size. The minimum acceptable character size was defined as the minimum character size that the participant could just recognize. The preferred character size was defined as the optimal character size that could be read quickly and comfortably. In order to let participants correctly select their personal minimum acceptable character size and preferred character size, they were encouraged to browse all of the 30 sample articles without time constraint. The selected character sizes were then transformed into subtending visual angles in min of arc.

2.3.2. Experimental design

A 2 × 3 mixed model factorial design was adopted for this investigation. The within subjects independent variable was the character size while the between subjects variable was age group (21–35, 36–49 and 50–70 years of age). Each subject had to separately perform two proof-reading trials with his/her minimum acceptable character size and preferred character size. Two similar but different proof-reading articles were selected from the meteorology text. The proof reading trial viewing screen was divided into two areas, i.e. up and down areas, as shown in figure 2. These two areas simultaneously presented the same context with 200
Chinese characters. The up area had correct words completely, but the down area had 12 errata. The errata were exclusive of punctuation. Two prepared articles were counter balanced and randomly assigned to the proof reading trials.

The dependent variables included proof reading speed and accuracy ratio for the proof reading trial. These two variables were combined as proof reading performance. The proof reading speed was calculated as 200 words divided by the task completion time (in sec). The accuracy ratio was defined as the amount of errata found by the participant divided by 12 errata.

2.3.3. Controlled variables

An earlier E-paper display study found that the ambient illumination effect on the preferred viewing distance was statistically significant (Shieh and Lee, 2007). Therefore, the ambient illumination was controlled to 500 ± 20 lux for all tests. Because the font type can affect the legibility and performance (Bernard et al., 2003; Chi et al., 2003; Ling and van Schaik, 2006), the font type should be constant in the proof reading tests. The font was set as Ming style because of its popularity among Chinese text presentation. The inclination angle of the bookrack was fixed to 45° with respect to the horizontal axis. Each participant maintained his/her preferred viewing distance across the two proof reading trials. The workplace factors (such as table and chair) were also the same for all tests.

2.4. Experimental procedures

After the preference test, the participant took a 10-min break and then performed the two proof reading trials in random order. The two proof reading articles were determined in advance with the character sizes at personal minimum acceptable character size and preferred character size, respectively. To avoid possible biases resulting from the visual fatigue effect, a
10-min rest period was given between the two proof reading trials. During each proof reading trial, the subject was instructed to find the wrong words in the text as quickly as possible and correct them on a sheet of paper. Each proof reading trial took about two or three minutes, depending on individual differences. When the participant completed each proof reading trial, the task completion time was recorded. The accuracy ratio was then calculated based on the correct number of modified words written by the subject.

2.5. Statistical analysis

In the preference test, the preferred viewing distance, minimum acceptable character size, and preferred character size were the three dependent measures. Analyses of variance (ANOVA) were performed to evaluate the age group effect on each of the three dependent measures. Further, the Student-Newman-Keuls (SNK) and treatment contrast tests were used for post-hoc comparisons if the age group effect was significant. The Pearson product-moment correlation analysis was also conducted to obtain the correlation coefficients between age and the measured variables from the preference test.

For the follow-up proof reading experiment, a MANOVA was performed consisting of a within subject factor (character size) and a between subject factor (age group) with the two dependent variables (proofreading speed and accuracy ratio). Univariate analyses were then performed to evaluate the character size and age group effects on each of the dependent variables. If the age effect was significant, the SNK post-hoc comparisons were also performed. All calculations were made with the SPSS_{12} software package. The level of the statistical significance was $\alpha = 0.05$.

3. Results
3.1. Preference test results

Subjects’ preferred viewing distance ranged from 336 to 622 mm, their minimum acceptable character size ranged from 22.7 to 59.5 min arc, and their preferred character size ranged from 29.7 to 76.0 min arc. Table 2 shows the mean values and standard deviations of the dependent measures under the three age groups.

The older the participant, the shorter the preferred viewing distance, as shown in table 2. The ANOVA result indicated that age group had a significant effect on preferred viewing distance \(F(2, 75) = 7.72, p < 0.01\). Post hoc comparisons showed that preferred viewing distance was significantly longer (503 mm) for the young group, while the difference between middle-aged (455 mm) and older groups (444 mm) was not statistically different, as shown in table 2.

[Insert table 2 about here]

As age increased, so did the minimum acceptable character size, as shown in table 2. The ANOVA results showed that age group had a significant effect on minimum acceptable character size \(F(2, 75) = 12.99, p < 0.01\). Post hoc comparisons showed that the older group had a significantly greater minimum acceptable character size (43.3 min arc) than the middle-aged group (38.6 min arc). The middle-aged group had a significantly greater minimum acceptable character size than the young group (32.5 min arc), as shown in table 2.

There was also a trend for increased preferred character size with increasing age, as shown in table 2. The ANOVA results revealed that age group also had a significant effect on preferred character size \(F(2, 75) = 17.05, p < 0.01\). Post hoc comparisons showed that the older group had a significantly greater preferred character size (55.2 min arc) than the middle-aged group (50.0 min arc). The middle-aged group had a significantly greater preferred character size than the young group (42.0 min arc), as shown in table 2.

Table 3 shows that age was significantly correlated with the preferred viewing distance \(r \)
It meant that older people tended to adopt closer viewing distance and prefer larger character size than the younger.

3.2. Proof reading test results

Table 4 shows the mean proof reading speed and accuracy ratio under the three age groups and two character sizes. There was a trend toward slower proof reading speed as age increased. The accuracy ratio tended to be greater under the preferred character size condition. The MANOVA results showed that the main effects of character size \( F(2,149) = 6.3, p = 0.002 \) and age group \( F(4,298) = 11.47, p < 0.001 \) were all significant on the total proof reading task performance. The interaction effect was not significant.

Univariate analyses indicated that proof reading speed was significantly affected by age group \( F(2,150) = 19.01, p < 0.01 \) but not significantly affected by character size \( F(1,150) = 0.085, p = 0.772 \). Post hoc comparisons between age groups indicated that the older group had a significantly \( (p < 0.05) \) slower proof reading speed (1.25 word/sec) than those in the middle-aged (1.74 word/sec) and young groups (1.76 word/sec), as shown in table 4. In contrast, the ANOVA results showed that the accuracy ratio was significantly affected by character size \( F(1,150) = 10.99, p = 0.001 \) but not significantly affected by age group \( F(2,150) = 1.12, p = 0.328 \). The preferred character size resulted in significantly higher accuracy ratio (73.3%) than that of the minimum acceptable character size (65.4%), as shown in table 4.

4. Discussion
4.1. Preferred viewing distance

This study maintained a constant E-paper type (Kolin) and varied the age of participants to evaluate the age effect on preferred viewing distance. The young group was found to have a significantly longer preferred viewing distance (503 mm) than the middle-aged (455 mm) and older groups (444 mm). That meant that middle-aged and older participants needed to shorten their distance to clearly read from the E-paper display even though they were using corrected lenses. This finding supports the hypothesis that older people would prefer a shorter viewing distance while wearing far-sighted glasses. This is perhaps because the elderly generally get far-sighted glasses in order to read a book in a short distance (around 30~40 cm). Consequently, far-sightedness in the elderly may be over-corrected with far-sighted glasses. Another cause may be that there is a general loss in the number of cones with increased age. Such losses may reduce visual acuity and perceptual ability. The elderly cannot see as clearly as the young although the elderly wear far-sighted glasses to focus on a close image. The elderly also have worse contrast sensitivity than the young. Kline and Schieber (1985) suggested that age-related structural changes in the eye, such as reduced papillary diameter and more opaque lens, may degrade the amount of light that can enter the eye and reach the retina. Age-related changes in the corneal surface may also degrade the quality of light entering the eye. Consequently, a shorter viewing distance was observed in elderly participants when reading from an E-paper display that had inadequate luminance contrast ratio \( \frac{L_{\text{background}}}{L_{\text{text}}} = 1.2 \).

The young group here had a mean preferred viewing distance of 503 mm, which is very close to the finding of Shieh and Lee (2007), 500 mm. This is because their study employed 18~28 year-old students as the subjects that were similar to the young group of our current study. Furthermore, Shieh and Lee (2007) indicated that preferred viewing distance for Kolin E-paper display (500 mm) was significantly longer than Sony E-paper display (491 mm).
Though the E-paper type had a significant effect on preferred viewing distance, it seemed to have no practical significance. This could easily be within the normal range of free head movement.

The preferred viewing distance of all the participants ranged from 336 to 622 mm, which were markedly shorter than the recommended minimum distance of 635 mm for desktop monitors (Ankrum, 1996) and the suggestion of 600 mm for computer screens (Hennings and Ye, 1996). This is because the E-paper display has a smaller screen size and lower luminance contrast than a VDT. People tend to prefer shorter viewing distance when reading from an E-paper display as compared with a VDT.

4.2. Preferred character size

One other objective of this study was to investigate the preferred character size for reading Chinese text from an E-paper display. The minimum acceptable character size was also collected here for follow-up comparisons between these two character sizes. The results indicated that the older group had a significantly greater preferred character size (55.2 min arc) than middle-aged group (50.0 min arc), and the middle-aged group had a significantly greater preferred character size than the young group (42.0 min arc). The preferred character size was about 10 min arc larger than the minimum acceptable character size. These findings for the young group are consistent with those of Wu and Chan (2006), because these two studies used the same type of E-paper display under similar illumination conditions.

As for the legibility of Chinese font size and style, Chi et al.’s study (2003) found that legibility thresholds for the four common font styles from the most to the least legible were in the Hei, Ming, Kai, and Li sequence. They suggested that the 95% cumulative probability of legibility in the Hei, Ming, Kai, and Li styles were 20.5, 22.7, 24.6 and 25.4 min arc, respectively. Their suggestions can be considered the minimum acceptable character size for
clearly presenting Chinese text on a VDT. However, the mean minimum acceptable character size for the young group in this study was 32.5 min arc, larger than the suggestions of Chi et al.’s study (2003). A possible explanation is that the luminance contrast of the E-paper display was 1:1.2 in this study, which was obviously worse than that of the VDT in Chi et al.’s study (2003). If the luminance contrast for E-paper display can be improved to 1:7 or better, the minimum acceptable character size may be reduced.

It should be noted that with the increase in age, both the minimum acceptable and preferred character sizes increased markedly (table 2). Chinese e-book designers must take into account that the character size requirement will differ among different age groups. It is best to provide a function for adjusting the font size to the users’ preference. Under personal preferred viewing distance, this study found: the young group (21~35 years) preferred 6.14 mm character height; the middle-aged group (36~49 years) preferred 6.62 mm character height; the older group (50-70 years) preferred 7.13 mm character height. Further, the minimum acceptable character height was about 1.5 mm smaller than the preferred character height.

4.3. Proofreading performance

This study adopted proof reading speed and accuracy ratio as the performance criteria for Chinese proof reading tasks. Age had significant effect on proof reading speed, but had little effect on accuracy ratio. A possible explanation is that the three age groups seriously proof read the articles with a similar degree of care, and the proof reading test had no time constraint. The young and middle-aged groups had significantly faster proof reading speed than the older group. This may be due to two reasons: (1) the older group’s perception and response functions dropped, resulting in slower proof reading speed, and (2) the young and middle-aged groups were mostly students or workers, who read frequently; therefore, they
had faster proof reading speed than the older group.

The character size effect had little effect on proof reading speed but a significant effect on the accuracy ratio. This is mainly because the difference between the two tested character sizes was not large enough to affect the proof-reading speed. The accuracy ratios increased from 65.4% to 73.3% as the character sizes increased from the minimum acceptable size to the preferred character size. This result implies that the minimum acceptable character size is not good enough to achieve the best identification performance. Previous studies have indicated that character size plays an important role in legibility and visual performance for the VDT (Sanders and McCormick, 1993). To a certain amount, larger character sizes are considered more readable than smaller sizes presented on VDTs (Kingery and Furuta, 1997; Snyder and Taylor, 1979). Further, Bernard et al. (2003) compared 3.5 mm (subtending 21 min arc) and 4.2 mm (subtending 25 min arc) character heights between Times and Arial typefaces in terms of objective and subjective text readability. Their experimental results showed that character height at 25 min arc produced significantly greater subjective readability and had lower levels of perceived difficulty in reading than text at 21 min arc, although a very small difference in reading time and accuracy was found between these two font sizes. Considering Chinese reading time and personal preference, Chan and Lee (2005) evaluated 3.5 mm and 5 mm character heights for reading Chinese articles from a VDT. These two character heights subtended visual angles of 26.7 and 38.2 min arc respectively. Their experimental results showed that character height at 38.2 min arc produced significantly faster reading speed, higher comprehension score and higher preference than a height of 26.7 min arc. In summary, we can note that people prefer larger font size and they may have better performance when reading from the larger font size regardless with a VDT or an E-paper display.
4.4. Limitations to this study

The preferred viewing distance and character size obtained in this study were based on subjective adjustment and selection during several minutes. The e-book Reader was fixed using a bookrack and the participant’s head was supported by a chin-support tripod after the preferred viewing distance was determined. The absence of observation on the behavior during prolonged reading makes it difficult to ascertain whether the preferred viewing distance will change through time. Some previous studies found that the VDT viewing distance is inversely related to the subjective visual fatigue (Shieh and Chen, 1997; Shieh, 2000). Therefore, the current obtained preferred viewing distance and character size may be applied only to a short reading task that has not yet produced visual fatigue. Further studies are necessary to investigate the changes in preferred viewing distance and character size during a prolonged reading task. The suggested preferred character sizes for young, middle-aged and older groups are applicable to a small E-paper display with 480 × 640 pixel resolution and around 1.2 luminance contrast ratio. A higher screen resolution or a greater luminance contrast ratio may produce better legibility, which will lead to a smaller preferred character size. Therefore, more studies are required to establish the relationship between the preferred character size and screen resolution as well as the luminance contrast ratio for different age groups, respectively.
E-paper displays need to be well designed for E-books to be read effectively and satisfactorily by different age groups. This study investigated the adequate character sizes for Chinese E-books for young, middle-aged and older adults in Taiwan. The results show that viewing distance and character size requirements will differ among different age groups. The older and middle-aged groups tended to prefer significantly shorter viewing distance (about 45 cm) than the young (about 50 cm). Under personal preferred viewing distance, this study found that the mean preferred character height was 6.1, 6.6, 7.1 mm for the young, middle-aged and older groups, respectively. The obtained preferred character height was about 1.5 mm greater than the minimum acceptable character height. The preferred character size could be considered large enough to improve identification performance because the proofreading accuracy ratio (73.3%) with the preferred character size was significantly better than that (65.4%) with the minimum acceptable character size. Because of aging, the older group had a significantly slower proof-reading speed than the young and middle-aged groups. The Chinese character sizes suggested for different age groups are applicable to a small E-paper display with 480 × 640 pixel resolution and around 1.2 luminance contrast ratio. It is recommended that existing VDT guidelines for design and E-paper displays be expanded to include a recommended viewing distance and character size for various age groups.
Acknowledgements

The author would like to thank the National Science Council of the Republic of China, Taiwan, for financially supporting this research under Contract No. NSC91-2213-E-324-030. All participants are commended for their efforts in the laboratory experiment.

References


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FIGURE LIST

Figure 1. The experimental setup for reading from the e-book Reader
Figure 2. The e-book screen layout and one example page of the proof reading trial
Table 1. Participants’ characteristics

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Young group 21-35 yrs</th>
<th>Middle-aged group 36-49 yrs</th>
<th>Older group 50-70 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)*</td>
<td>25.2 (3.6)</td>
<td>43.0 (2.8)</td>
<td>53.9 (5.2)</td>
</tr>
<tr>
<td>Percentage of near-sighted</td>
<td>92.3%</td>
<td>61.5%</td>
<td>53.8%</td>
</tr>
<tr>
<td>Percentage of far-sighted</td>
<td>0%</td>
<td>42.3%</td>
<td>88.5%</td>
</tr>
<tr>
<td>Percentage of both near-sighted and far-sighted</td>
<td>0%</td>
<td>34.6%</td>
<td>50.0%</td>
</tr>
<tr>
<td>Percentage having experience with the PDA or small screen displays</td>
<td>34.6%</td>
<td>7.7%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Self-reported reading time per day (min/day)*</td>
<td>114 (48)</td>
<td>107 (44)</td>
<td>91 (53)</td>
</tr>
</tbody>
</table>

* Data are presented in mean (standard deviation)
Table 2. Participants’ preferred settings in the preference test

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>n</th>
<th>Preferred viewing distance (mm)</th>
<th>Minimum acceptable character size (minute arc)</th>
<th>Preferred character size (minute arc)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (SD) mark(^a)</td>
<td>Mean (SD) mark(^b)</td>
<td>Mean (SD) mark(^c)</td>
</tr>
<tr>
<td>Age group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>26</td>
<td>503 (50) A</td>
<td>32.5 (5.1) A</td>
<td>42.0 (5.5) A</td>
</tr>
<tr>
<td>Middle-aged</td>
<td>26</td>
<td>455 (54) B</td>
<td>38.6 (7.6) B</td>
<td>50.0 (8.5) B</td>
</tr>
<tr>
<td>Older</td>
<td>26</td>
<td>444 (68) B</td>
<td>43.3 (9.7) C</td>
<td>55.2 (9.9) C</td>
</tr>
</tbody>
</table>

\(^a\) Means followed by the same letter are not significantly different as determined by SNK post-hoc comparisons at the significant level of \(p = 0.05\).
Table 3. Pearson product-moment correlation matrix (n=78)

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Estimated daily reading time</th>
<th>Preferred viewing distance</th>
<th>Minimum acceptable character size</th>
</tr>
</thead>
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<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated daily reading time</td>
<td>-0.144</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred viewing distance</td>
<td>-0.382**</td>
<td>-0.213</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum acceptable character size</td>
<td>0.505**</td>
<td>0.109</td>
<td>-0.698**</td>
<td></td>
</tr>
<tr>
<td>Preferred character size</td>
<td>0.564**</td>
<td>0.099</td>
<td>-0.733**</td>
<td>0.836**</td>
</tr>
</tbody>
</table>

**Significant at p < 0.01
Table 4. Proof reading experimental results under three age groups and two character sizes

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>n</th>
<th>Proof reading speed (word/sec)</th>
<th>Accuracy ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (SD) mark</td>
<td>Mean (SD) mark</td>
</tr>
<tr>
<td>Age group*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>52</td>
<td>1.76 (0.47) A</td>
<td>70.8 (11.8) A</td>
</tr>
<tr>
<td>Middle-aged</td>
<td>52</td>
<td>1.74 (0.51) A</td>
<td>70.4 (14.2) A</td>
</tr>
<tr>
<td>Older</td>
<td>52</td>
<td>1.25 (0.46) B</td>
<td>66.8 (18.9) A</td>
</tr>
<tr>
<td>Character size*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum acceptable character size</td>
<td>78</td>
<td>1.57 (0.55) #</td>
<td>65.4 (15.4) #</td>
</tr>
<tr>
<td>Preferred character size</td>
<td>78</td>
<td>1.59 (0.52) #</td>
<td>73.3 (14.2) &amp;</td>
</tr>
</tbody>
</table>

* The main effect was significant on the total proof reading performance determined by MANOVA at the significant level of $p = 0.05$.

* Means followed by the same letter are not significantly different between age groups as determined by SNK post-hoc comparisons at the significant level of $p = 0.05$; Means followed by the same symbol are not significantly different between character sizes as determined by univariate analyses at the significant level of $p = 0.05$. 

Figure 1. The experimental setup for reading from the e-book Reader
Figure 2. The e-book screen layout and one example page of the proof reading trial