原　著

How Well the Elderly Evaluate the Readability of E-paper Devices: Standardization of Minimum Legible Character Size

高齢者は電子ペーパー機器をどのくらい読みやすいと評価しているか？ ---- 最小可読文字サイズの標準化について

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Abstract

Electronic Paper Displays (EPD) are similar to conventional paper and recently widely introduced to e-books. And backlit Liquid Crystal Displays (LCD) has been popular for long years. Although the readability of LCDs were studied well, that of EPD has not been fully investigated. In this experiment, we asked different age groups of participants to evaluate the effects of font sizes of two different e-book devices (EPD: Kindle Voyage and LCD: Apple iPad) on the readability. We set the text character sizes at four levels; 4 pt (character height: 1.4 mm), 6 pt (2 mm), 8 pt (2.75 mm), and 12 pt (3.25 mm). The study measured reading speed, correct answer rate and a subjective evaluation. Our study found that those under 64 years of age could maintain their performance of readability when the fonts were 6 pt size or higher. Those participants over 65 years of age could sufficiently read at the 8 pt font size. The participants found that the readability of the both E-books was equal to the performance of each other and also equal to paper text. Therefore, E-paper display designed to function similar to paper can contribute to improving readability, especially for the elderly. On the basis of this study, we recommend a default setting higher than 8 pt (2.75 mm) should be displayed on the screens of E-papers.

抄録

電子ペーパー・ディスプレイ（EPD）は従来の紙とよく似ており、近年電子書籍に広く導入されている。また、バックライト型液晶ディスプレイ（LCD）は、以前から電子書籍などに広く利用されてきた。ここで、液晶ディスプレイの可読性に関しては多くの研究が発表されているが、電子ペーパーの可読性についての研究は未だ不充分である。本研究では、種々の年令層を含む実験参加者によって、２種の電子書籍（Kindle Voyage と Apple iPad）における、４種の文字サイズの可読性への影響を評価させた。設定した４種の文字サイズは、4 pt（文字高：1.4 mm）、6 pt（2 mm）、8 pt（2.75 mm）、および 12 pt（3.25 mm）であった。実験では、読みスピード、正答率、および読みやすさの主観評価が計測された。実験結果から、64 歳以下では文字サイズが 6 pt 以上ならば読みやすいことが判明した。他方、65 歳以上の高齢者では、文字サイズが 8 pt 以上ならば読みやすかった。今回の実験で、２種の電子書籍、及び従来の紙のどれもが、ほぼ同様に読みやすいことがわかった。電子ペーパーは、紙とよく似ているが、とくに高齢者に対しては、画面を拡大することができるので読みやすい。本研究の結果から、電子ペーパーに表示する文字サイズに、8 pt（2.75mm）の文字高を標準として推奨する。

Keywords: Readability of E-paper, Font Sizes, Aging, Standards

キーワード：電子ペーパーの可読性、文字サイズ、加齢、標準化

1 Introduction

At present, manufacturers of e-paper devices are striving to improve the visual performance of their products to be equal to or better than conventional paper[1]. Technically, electronic paper display (EPD, such as a Kindle Voyage) uses E-ink. E-ink is consisted of black and white particulates through a process of electrophoretic display, while a device such as an iPad uses a Liquid Crystal Display (LCD)[2]. Both devices have their advantages and disadvantages particularly with regard to long term reading such as from e-books. The interest in e-books is growing and appears to be expanding for all ages, but questions have arisen regarding their functionality relative to conventional paper. The aim of this study was to compare the readability of different font sizes on the two devices and to estimate minimum legible character size and to obtain such standard.

In this study, participants of different ages took a silent reading test and then evaluated the readability four different font sizes used on two electronic devices (Kindle Voyage and Apple iPad). The experiment looked at the reading performance of the participants for each of the four font sizes (4, 6, 8, 12 points). By testing to see if there was a significant decrease in reading speed and the correct answer rates with the font sizes, the aim was to uncover the minimum readable font size for each of the various age groups. In addition, we wished to evaluate to what degree these devices matched the functionality of conventional paper text.

2 Methods

2.1 Participants

The readers for this experiment include 80 males and females between the ages of 14 and 79 years (M 46.7, SD 17.9). Participants who usually wore glasses or contact lenses used them for the experiments. The experiment received approval from the Ethical Review Board of the Graduate School of Information Science at Nagoya University after we obtained informed consent from all the participants.

Table 1 shows the number of participants divided into age groups. The participants were divided into four general groups according to their age: young (29 years and younger), middle-aged (30 to 44 years old), senior middle-aged (45 to 64 years old), and elderly (65 years and older).

Table 1. Participants divided by age groups

	Young	Middle	Senior Middle	Elderly	Total
Exp.	20	17	28	15	80

Table 2. Participant lens cloudiness

	Young Mean±S.D	Middle Mean±S.D	Senior Middle Mean±S.D	Elderly Mean±S.D
Exp.	42.5±10.0	70.7±17.4	98.5±30.1	162.1±43.7

† The range of cloudiness gradation is 0 to 255.

We measured the cataract cloudiness of each of the readers with an Anterior Eye Segment Analysis System (NIDEK EAS-1000). Table 2 shows the measured values of the readers divided into their respective age groups. The youngest group had sufficient amplitude of lens accommodation. The middle-aged group had sufficient near vision ability, although their accommodation was slightly weaker. The senior middle-aged group had mild presbyopia and problems in near vision work. The elderly group had typical presbyopia and generally had to wear glasses for close vision.

2.2 Experimental design

In this experiment, we also employed three types of devices, an e-paper (Amazon Kindle VoyageTM), a backlit LCD (Apple iPadTM), and as a reference, conventional paper text (with the text printed on PPC paper of 69 % whiteness)[3,4]. Table 3 shows the technical specifications for each of the display devices. In short, we refer to the Kindle Voyage as KV, the Apple iPad as iPad, and the conventional paper as simply Paper.

Table 3. Device specifications

	Kindle Voyage	iPad	Paper
Screen size	6 inch	9.7 inch	6 inch
Resolution	300 ppi	264 ppi	1200dp

In order to alleviate the possibility of reader bias from brand recognition, the participants read the different texts from a bezel covered with white Kent paper with only the screen showing. The test media or test paper was mounted on the center of a board. The text displayed for each medium was set at the same height. The front light level of the KV and the back light level of the iPad were set to maximum levels. The text color was black/dark, and the background color was white/bright.

Figure 1 shows the screen luminance for each device. As expected, the screen luminance for the KV showed similar results to conventional paper. In addition, we calculated the contrast ratios from the measured values of the brightness of the background color and text color (Figure 2). The iPad had a higher contrast ratio compared to the other devices because it showed a lower screen luminance of black/dark and a higher screen luminance of white/bright.

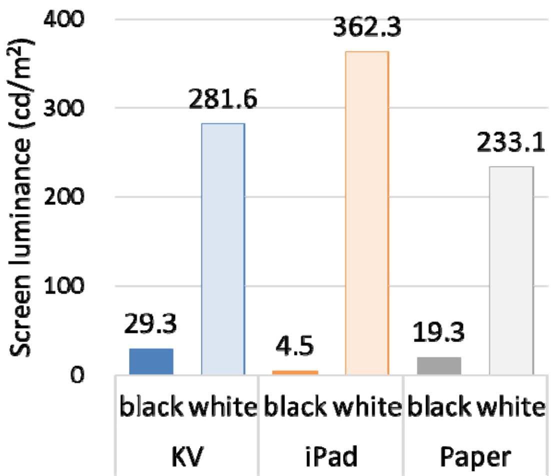


Figure 1. The screen luminance with black letters and white background

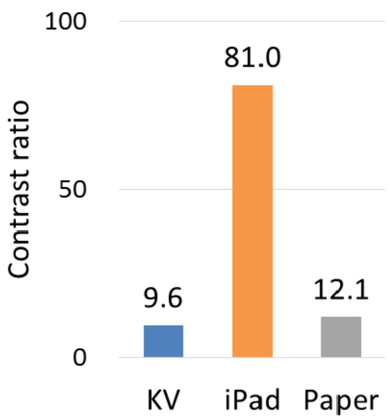
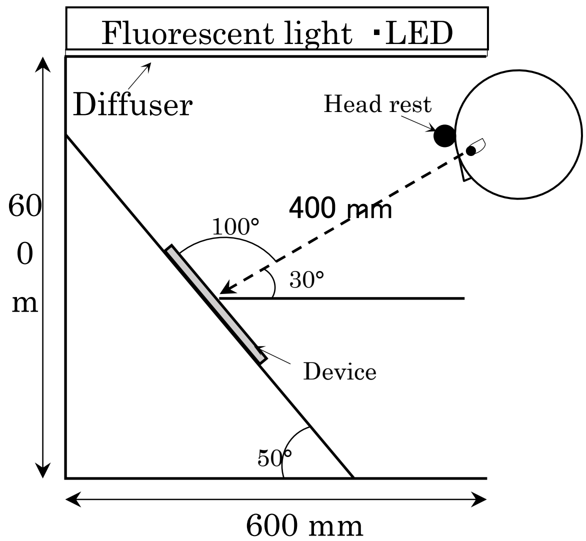


Figure 2. The contrast ratio of each device

The participants sat in a cubicle that had a compartmental lighting system placed on a desk in a darkened room (Figure 3). This experiment followed the lightning system created in a previous study in order to be consistent[5,6]. The headrest for the participant's forehead was kept at a visual distance of 400 mm. The participants looked at the devices at an angle of about 100 degrees to eliminate any problems with self-reflection.

The experiment was conducted at an illuminance level of 1,000 lx using a 6500 K LED light source with a fluorescent lamp that had a uniform color temperature. The International Organization of Standards (ISO) recommends an illuminance level of 1,000 lx for doing precision work in an office[7].



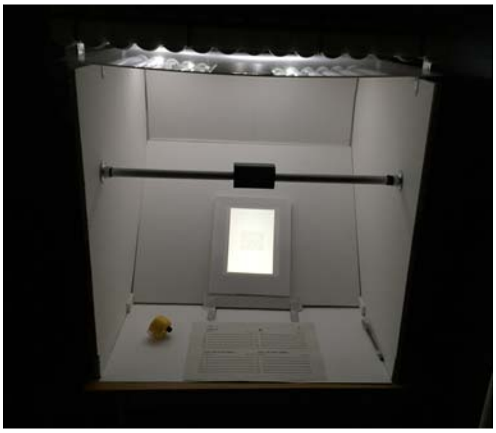


Figure 3. The setup for reading

2.2 Task design

The display format conformed to that used for evaluation of electronic display devices by the

International Organization for Standardization (ISO)[8].

The experimental task was a block reading test of a short duration (Figure 4). We used random alphanumeric text and unified the size of the characters. The font type was Courier for both experiments because it is a uniform monospaced font that has a slight serif ("bearded"). A monospaced font is one with a fixed width; that is, each letters occupies the same amount of horizontal space[9].

```
LcBs ENckC gplY ELOjPxasTPtAxa
hQ mpU cq VwFdihGamGMztI sj ov
mn KCU QNY hoGqw oS Fa DmsUiLG
BDIqUrGx gLfdaehwd XNj ELdP tL
wYsfmlQa USIg xb BavcTslj QBFv
dK Mb tBH FNcLjY lqZrZN GfrdjC
XSlL NdyTt sa XH wCIIcT rernDq
IEDr vJBpc RvibD LdzY QXb NqEI
kUx zMkm JSxg wmHGF Ltw AOkPjd
BtT xzjT YAI bjYHII AQ vQa Goh
bY nlZ uiVPGzP SZf pH nrzv jDa
tqBBpkRmv QqX AjMGzoJBOrvpKrCZ
Ecwgo zJ ZdyObJn YOz PDBOmzneT
aOe sdNlDL SrysCAcmxbTrMQ sRmA
```

Figure 4. Example of text block for the reading task

As the width of the characters for Courier is uniform, our focus was with the height of the font size. The font sizes were set at 4 pt (approx. 1.5 mm height), 6 pt (2 mm), 8 pt (2.75 mm), and 12 pt (3.25 mm). Figure 4 shows the example of the text blocks for the reading task. The participants performed twelve separate reading tests (four fonts per each of three devices). We had participants read the text silently from the top left and then we measured for speed and correct answer rate.

The participants were asked to count the number of capital letter "*M*" s in the total text with a counter as they read through the characters. We calculated the correct answer rate from the number of "*M*" s that the participants found and the actual number of these letters in the text. The correct answer rate was not entirely exact because the participants sometimes misread other alpha characters as large "*M*" s.

The reading time index and correct answer rate index were divided by the average values of each of the participant's total values in order to standardize the performance of all the readers. A high-scoring reading time index meant that it took the participant a long time to complete a task. The high scoring correct answer rate index indicated that there was a large number of correct answers.

After each reading, the participants also evaluated the readability of the texts using a Visual Analog Scale (VAS). We converted the values of the VAS into a 100-point scale in the final analysis. Figure 5 provides an example of a subjective evaluation using the VAS method. A high-score on the VAS signified that a participant found a device to be very readable. In terms of the scale, a score of zero could result from extreme difficult to read or for missing values such as when the reading time or answer rate could not be scored.

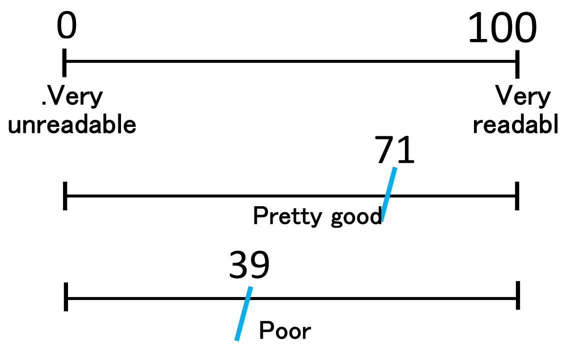


Figure 5. Example of evaluations by VAS

We used a two-way analysis of variance (two-way ANOVA) as a statistical method to evaluate the final results between the reading time, correct responses and the subjective evaluations. In addition, we also used a one-way analysis of variance (ANOVA) and the Scheffé multiple comparison procedure in order to comprehend the importance of the different age groups.

3 Results

Table 4 shows the results from the two-way ANOVA for the participants' evaluation (VAS), reading time index, and correct answer rate index. The VAS, reading time index, and correct answer rate index showed significant differences between the font sizes ($p<0.01$), but no significant differences were observed among the types of devices.

Table 4. Two-way ANOVA for the VAS, reading time index and correct answer rate index

Source	Df	SS	MS	*F*	
VAS					
Type of device(D)	2	940.79	470.40	1.33	
Character size(C)	3	504425.46	168141.82	474.42	**
D×C	6	1511.56	251.93	0.71	
Reading time index					
Type of device(D)	2	0.110	0.055	2.867	
Character size(C)	3	6.074	2.025	105.514	**
D×C	6	0.118	0.020	1.028	
Correct answer rate index					
Type of device(D)	2	0.006	0.003	0.066	
Character size(C)	3	13.231	4.410	99.109	**
D×C	6	1.792	0.299	6.713	

† **; p<0.01

Table 5 provides a multiple comparison for the VAS, reading time index, and correct answer rate index. The VAS scores for the 4 pt font size (app 1.5 mm) were significantly lower than those of more than 6 pt size (2 mm). In fact, the scores were significantly different between each of the font sizes. The reading time index was significantly longer for the smaller font sizes. The correct answer rate index was also significantly lower per smaller font size.

The results from two-way ANOVA established that the font sizes had an effect on the readability

Table 5. Multiple comparison for the VAS, reading time index, and correct answer rate index

	VAS (Mean±S.D.)		Reading time index (Mean±S.D.)		Correct answer rate index (Mean±S.D.)	
4 pt	12.2 ± 12.4	a**, b**, c**	1.112 ±0.189	a**, b**, c**	0.795 ± 0.301	a**, b**, c**
6 pt	36.4 ± 19.9	a**, d**, e**	1.077 ±0.179	a**, d**, e**	1.011 ± 0.162	a**, d*, e**
8 pt	56.4 ± 21.7	b**, d**, f**	0.932 ±0.142	b**, d**	1.065 ± 0.182	b**, d*
.2 pt	73.6 ± 19.7	c**, e**, f**	0.932 ±0.104	c**, e**	1.112 ± 0.192	c**, e**

† Values in the same column with the same letters are significantly different (**; p<0.01)
† For example, 4 pt and 6 pt in the Participants' evaluation column are given the letter 'a'. This means that the subjective evaluation of 6 pt character size is significantly better than that of 4 pt.

of the devices. Therefore, we next compared the character sizes for each age group using a one–way ANOVA. Table 6 and Figure 6 show a comparison of the VAS by font sizes for each age group. For all age groups, the VAS scores for each font size was significantly lower as character point became smaller.

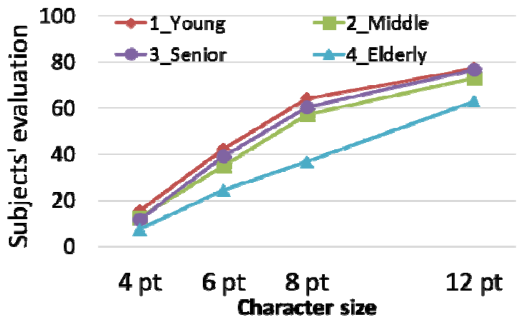


Figure 6. Subjects' evaluations under four character sizes

Table 6. Subjects evaluations of four fonts

	1_Young Mean±S.D		2_Middle Mean±S.D		3_Senior Mean±S.D		4_Elderly Mean±S.D	
4 pt	15.7 ± 13.3	a**, b**, c**	12.7 ± 12.2	a**, b**, c**	11.7 ± 12.7	a**, b**, c**	7.7 ± 8.6	a**, b**, c**
6 pt	42.3 ± 16.9	a**, d**, e**	35.0 ± 16.9	a**, d**, e**	39.2 ± 20.2	a**, d**, e**	24.7 ± 21.3	a**, d**, e**
8 pt	64.2 ± 17.2	b**, d**, f**	57.4 ± 19.5	b**, d**, f**	60.6 ± 19.4	b**, d**, f**	37.0 ± 22.3	b**, d**, f**
12 pt	77.3 ± 16.9	c**, f**	73.4 ± 18.3	c**, f**	76.8 ± 18.3	c**, f**	63.2 ± 23.3	c**, f**

† Values in the same column with the same letters are significantly different (**; p<0.01)
† For example, 4 pt and 6 pt in the Subjects' evaluation column are given the letter 'a'. This means that the subjective evaluation of 6 pt character size is significantly better than that of 4 pt

Table 7 and Figure 7 show a comparison of the reading time index by font size for each age group. The reading time index for the younger and middle aged groups was significantly longer for the 4 pt. The reading time index for the senior middle aged group was significantly longer between the 6 pt and 8 pt sizes. The reading time index of the elderly group was significantly longer at each font size between the 4 and 8 pt sizes. The elderly readers showed no significant difference between the 4 pt and 6 pt sizes compared to the other age groups.

Table 8 and Figure 8 show a comparison of the correct answer rate index per font size for each age group. The correct answer rate index of all age groups for the 4 pt size was significantly lower than those of more than 6 pt. The correct answer rate index of the middle aged group for 6 pt was significantly lower than that of 12 pt size. The differences in the proportion of slopes in the line graph (fig 8) for the young and middle aged groups were smaller than those for the senior middle aged and elderly groups. The correct answer rate index

Table 7. Reading time index under four character sizes

	1_Young Mean±S.D		2_Middle Mean±S.D		3_Senior Mean±S.D		4_Elderly Mean±S.D	
4 pt	1.132 ± 0.152	a**, b**, c**	1.104 ± 0.109	a*, b**, c**	1.161 ± 0.149	a**, b**, c**	1.112 ± 0.189	a**, b**
6 pt	0.996 ± 0.109	a**	0.991 ± 0.292	a*	1.011 ± 0.146	a**, d**, e**	1.077 ± 0.179	c**, d**
8 pt	0.936 ± 0.084	b**	0.952 ± 0.095	b**	0.919 ± 0.080	b**, d**	0.932 ± 0.142	a**, c**
12 pt	0.936 ± 0.112	c**	0.952 ± 0.103	c**	0.920 ± 0.081	c**, e**	0.932 ± 0.104	b**, d**

† Values in the same column with the same letters are significantly different (**; p<0.01, *; p<0.05) using ANOVA & the Scheffé multiple comparison procedure.

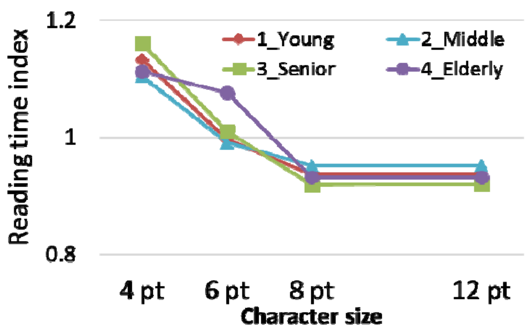


Figure 7. Reading time index under four character sizes

Table 8. Correct answer rate index under four character sizes

	1_Young Mean±S.D		2_Middle Mean±S.D		3_Senior Mean±S.D		4_Elderly Mean±S.D	
4 pt	0.939 ± 0.200	a*, b** c**	0.896 ± 0.210	a*, b**, c**	0.732 ± 0.299	a**, b**, c**	0.486 ± 0.334	a**, b**, c**
6 pt	0.997 ± 0.125	a*	1.006 ± 0.150	a*, d*	1.033 ± 0.128	a**	0.988 ± 0.262	a**
8 pt	1.021 ± 0.129	b**	1.013 ± 0.161	b**	1.091 ± 0.16	b**	1.132 ± 0.26	b**
12 pt	1.042 ± 0.113	c**	1.085 ± 0.138	c**, d*	1.124 ± 0.145	c**	1.213 ± 0.318	c**

† Values in the same column with the same letters are significantly different (**; p<0.01, *; p<0.05) using ANOVA & the Scheffé multiple comparison procedure.

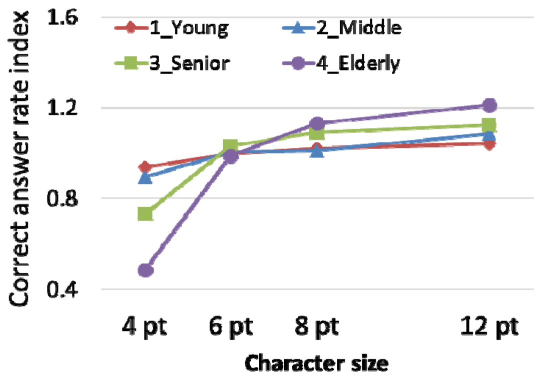


Figure 8. Correct answer rate index under four character sizes

for the 4 pt decreased greatly in the older groups. Because the correct answer rate index had the most difference for each age group among all the indices, we analyzed the data by types of devices for each age group by using a one-way ANOVA.

Table 9 and Figure 9 show the correct answer rate index for the younger group of readers. The KV had significantly lower ratings between the 6 and 8 font sizes. No significant difference was observed among the font sizes for the iPad, while 4 pt size was significantly lower than the 6 pt for the Paper text.

Table 9. Correct answer rate index in the younger

	1_KV (Mean±S.D.)	2_iPad (Mean±S.D.)	3_Paper (Mean±S.D.)
4 pt	0.893 ± 0.191 a**, b*	1.070 ± 0.126	0.854 ± 0.204 a**, b**, c**
6 pt	0.931 ± 0.129 c*	1.011 ± 0.112	1.051 ± 0.103 a**
8 pt	1.065 ± 0.085 a**, c*	0.965 ± 0.150	1.034 ± 0.124 b**
12 pt	1.018 ± 0.104 b*	1.030 ± 0.124	1.079 ± 0.099 c**

Values in the same column with the same letters are significantly di†fferent (**; p<0.01, *; p<0.05) using ANOVA & the Scheffé multiple comparison procedure.

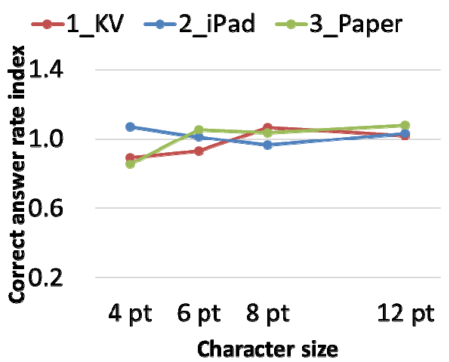


Figure 9. Correct answer rate index in the younger group

Table 10 and Figure 10 show the correct answer rate index for the middle aged group. For the KV, the 4 pt size was significantly lower than those of more than 8 pt. No significant difference was observed among character sizes with the iPad, while the 4 pt size was significantly lower than those of more than 6 pt.

Table 10. Correct answer rate index in the middle aged group

	1_KV (Mean±S.D.)	2_iPad (Mean±S.D.)	3_Paper (Mean±S.D.)
4 pt	0.888 ± 0.199 a*, b**	0.960 ± 0.167	0.839 ± 0.239 a**, b**, c**
6 pt	1.026 ± 0.168	0.970 ± 0.120	1.023 ± 0.150 a**
8 pt	1.060 ± 0.095 a*	0.922 ± 0.172	1.058 ± 0.165 b**
12 pt	1.092 0.136 b**	1.029 0.148	1.134 0.105 c**

† Values in the same column with the same letters are significantly different (**; p<0.01, *; p<0.05) using ANOVA & the Scheffé multiple comparison procedure.

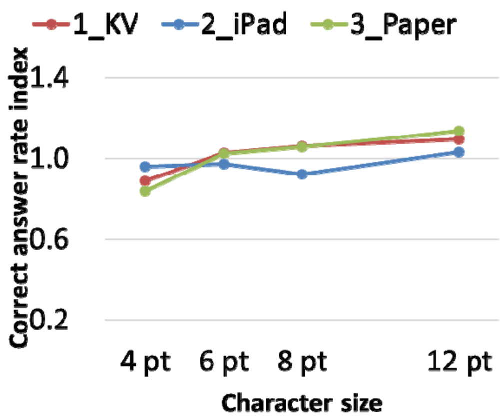


Figure 10. Correct answer rate index in the middle aged group

Table 11 and Figure 11 show the correct answer rate index for the senior middle aged group. For all devices, the 4 pt size was significantly lower than those of more than 6 pt size. For this age group, there was no significant difference in the correct answer rating between the 6 pt and 12 pt sizes.

Table 12 and Figure 12 show the correct answer rate index for the elderly group. For the KV and iPad, the answers were significantly lower at the 4 pt size compared to more than 6 pt size. For paper, the 4 pt size was significantly lower than the 6 pt size which in turn was significantly lower than that of the12 pt

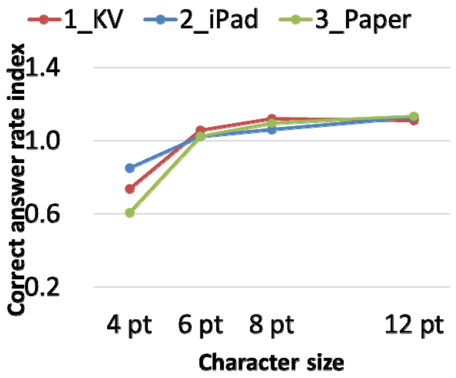


Figure 11. Correct answer rate index in the senior middle aged

Table 12.Correct answer rate index in the elderly group

	1_KV (Mean±S.D.)		2_iPad (Mean±S.D.)		3_Paper (Mean±S.D.)	
4 pt	0.434 ± 0.286	a**, b**, c**	0.554 ± 0.356	a*, b**, c**	0.452 ± 0.333	a**, b**, c**
6 pt	1.018 ± 0.289	a**	0.957 ± 0.233	a*	0.986 ± 0.255	a**, d*
8 pt	1.023 0.269	b**	1.116 0.253	b**	1.254 0.197	b**
12 pt	1.194 0.251	c**	1.134 0.389	c**	1.310 0.270	c**, d*

† Values in the same column with the same letters are significantly different (**; p<0.01, *; p<0.05) using ANOVA & the Scheffé multiple comparison procedure.

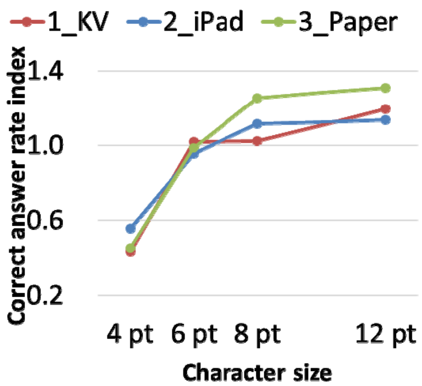


Figure 12. Correct answer rate index in the elderly group

size. The differences in the proportion of the slopes in the line graph (fig 12) for font sizes in the young and middle aged groups were smaller than those of the senior middle aged and elderly groups. For the older group, the correct answer rate index for the 4 pt font decreased significantly compared to the other groups. This was especially true for the rating of the reading from the KV (p<0.01).

4 Discussion

The primary aim of this experiment was to identify how well different groups evaluated the readability of different font sizes for two types of electronic devices. This experiment was conducted under 1,000lx of illuminance to eliminate the effect of ambient illuminance on the readability of the e-paper. In our previous studies, we found no significant differences on the readability of an e-paper, LCD, and paper at the 1,000 lx level[10,11].

We used the Courier font type because it is a monospaced font recommended for such studies by the ISO[7]. In addition, in order to conform to our previous studies, we measured the character heights in millimeters to ensure compatibility. Studies have reported that Courier is a viable font for the elderly suffering with vision problems including macular degeneration[12].

This experiment sought to identify what would be the lower limit font height at which participants could maintain their reading performance. We tested for reading speed and correct answer rate, while also looking at how font sizes effect readability for older individuals. We set the text font sizes at four levels; 4 pt (character height: 1.4 mm), 6 p (character height: 2 mm), 8 pt (character height: 2.75 mm), 12 pt (character height: 3.25 mm).

In this study the VAS scores for 8 pt font size showed an average evaluation scores above 50. We found that the participants felt that the character height of more than 2.75 mm (8pt) was sufficiently readable. The reason may have been due to lighting differences or the differences in resolutions. The screen resolutions for both the KV and iPad were well above 150 ppi (Table 3). Previous studies have shown that participants' evaluations of readability were higher when resolutions of the device were between 150 ppi to 400 ppi[13].

In this study, the 4 pt font size for all the devices showed significantly low values for participant evaluations, reading time index, and correct answer rate index. Lee et al. also reported that the legibility of the 1.4 mm character height size was lower than that of 2.2 mm[14]. The results in this study also suggests that the minimum font size at which participants (64 years old or younger) can maintain their reading performance for an e-paper is at about 2 mm (6 pt).

Furthermore, the VAS scores were plotted as an increasing straight-line from the 4 pt to 8 pt font sizes (fig 6). There was a gentle curve that represented a significant increase in the scores between the 8 pt and 12 pt font sizes. In this study, we found that the character height size of 2.75mm (8 pt font size) was the lower limit to which reading speed decreased significantly. The correct answer rate index showed that a significant increase between 4 pt and 6 pt ($p<0.01$), and some increase between 6 pt and 8 pt ($p<0.05$).

There was no significant difference between the 8 pt and 12 pt font sizes. Thus, we can suggest that the lowest limit that participants can read words accurately is the character height size of 2.75mm (8 pt font size) for e-paper devices. The LCD with a backlit assisted those under the middle aged group with reading proficiency with font sizes less than 2 mm (6 pt)., but was not helpful for those in the older group.

Table 2 showed that the elderly suffer from higher cataract cloudiness compared to younger people. One of our previous studies reported that high cataract cloudiness decreased the ability to read from tablet devices[15]. Cataract cloudiness plays a role similar to frosted glass which can diminishing effect on how light enters the eye. Thus, while the minimum font size for most individuals might be at 2 mm (6 pt), the elderly could only maintain performance at 2.75 mm (8 pt).

This experiment supported previous studies which found that readability of e-books for older people is affected by poor conditions such as low ambient illuminance and low screen contrast ratios[16,17]. This study buttresses our other research findings which show the LCD and e-paper are only more advantageous to conventional paper because the font sizes can be easily changed by the reader[18].

5 Conclusion

This study investigated the effects of font sizes and aging on the readability of e-books. The findings in this experiment can be summarized based on the readability of the font size and the devices.

5.1 Font sizes

(1) The participants felt that the screen font size (character height) of 2.75 mm (8 pt) was readable. For all ages, we recommend a font size of more than 2.75 mm as a default size displayed on the screens of electronic devices.

(2) The minimum font size level at which those readers under 65 years of age could maintain their performance (there was no decrease in reading speed and correct answer rate) was the character height of 2 mm (6 pt). The visual performance of those over 65 years of age decreased in below 2.75 mm.

(3) All groups saw a decrease in reading speed below the 2.75 mm (8 pt) font size. As a result we recommend this size as the minimum limit.

5.2 Devices

(1) The readability of the two electronic devices we used in this study performed equally to paper text. However, these devices are more advantageous because they allow the reader the opportunity to the change font sizes. This is particularly helpful to the elderly.

(2) The front lighting system on e-papers works well for improving readability. Furthermore, reading is improved when the screen resolution is greater than 150 ppi.

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