

Comparison of Age Groups on the Readability of an E-Reader with a Built-in Light

Yuki Ishii, Tatsuya Koizuka, Kohei Iwata, Takehito Kojima,
Paul Lege, and Masaru Miyao^(✉)

Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi, 468-8603, Japan
callistemon.r.br@gmail.com, miyao@nagoya-u.jp

Abstract. We carried out experiments to evaluate the readability of e-paper devices using different systems. In the experiments, we conducted subjective evaluations under staged illuminance conditions. This study found that different age groups showed differences in reading e-paper devices with a built-in light under different conditions of illuminance.

Keywords: Evaluation of accessibility · Usability · User experience · E-books · E-paper · Kindle DX · Ipad · Readability · Illuminance

1 Introduction

As display technologies have advanced in recent years, there has been an increase in high quality content on mobile devices, such as smart phones, tablet devices or e-readers. In addition, the number of mobile devices has increased rapidly in recent years and such devices are used by both young and old. The spread of e-books has been helped by e-readers that specialize in the clarity of the text. Most e-readers have an e-paper display system, and people can read these as easily as reading a paper text even when outdoors. Our previous study showed that under conditions of low illuminance, the readability of the e-paper was poor [1]. However, a built-in light system could improve the readability of the e-paper under low illuminance conditions (e.g. Kindle Paperwhite [2]). Compared with the young, the elderly have lower visibility. In this study, we carried out reading experiments to evaluate the readability of e-paper with built-in light. We investigated the contributions of built-in light on the readability of e-paper devices by age groups.

2 Method

2.1 Subjects

The subjects for this study included 110 healthy males and females between the ages of 19 and 86 years (Table 1). The subjects who usually wore glasses or contact lenses used them for the experiments. We obtained informed consent from all subjects and approval for the study from Ethical Review Board in the Graduate School of Information Science at Nagoya University.

Table 1. The age groups of the subjects

	Age groups	The number of people	Average	Standard deviation
Young	19–4	44	27.5	7.2
Middle	45–64	45	50.9	4.2
Elderly	65–86	21	72.8	5.0

2.2 Experimental Design

We carried out the reading experiments in a darkened room. In order to adjust to constant illumination, we used an original lighting system consisting of a fluorescent light and LED for reading. In the experiment, the illumination was adjusted to 14 levels. Table 2 shows both the target illuminance and measured illuminance values.

Table 2. Target illuminance and measured illuminance values (lx)

10	20	50	100	150	200	300	500	750	1,000	1,500	2,000	5,000	8,000
13.47	22.73	51.60	101.4	151.4	176.3	261.7	516.7	787.7	1,042	1,591	1,983	4,670	8,017

In the experiment, we used an e-reader with built-in light (Kindle Paperwhite released in 2012) and e-reader without built-in light (Kindle DX released in 2009). We also used backlit LCD (iPad released in 2012) and conventional paper text. We used the Kindle Paperwhite and iPad at a configuration of maximum brightness. We put the reading devices in small compartments placed on a desk (Figs. 1 and 2).

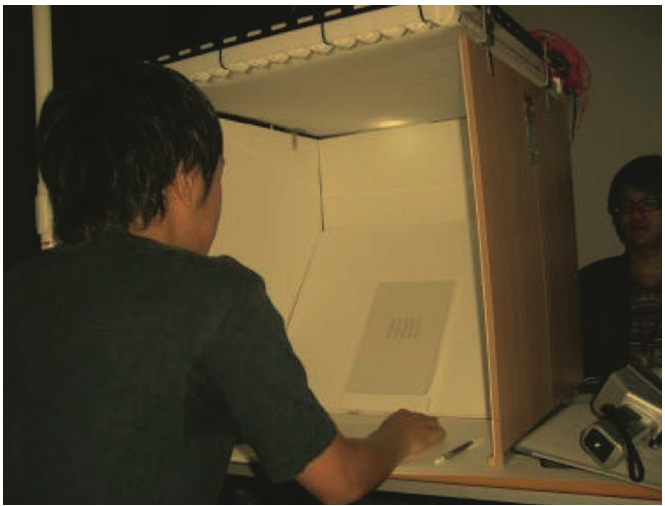


Fig. 1. Appearance of experiment

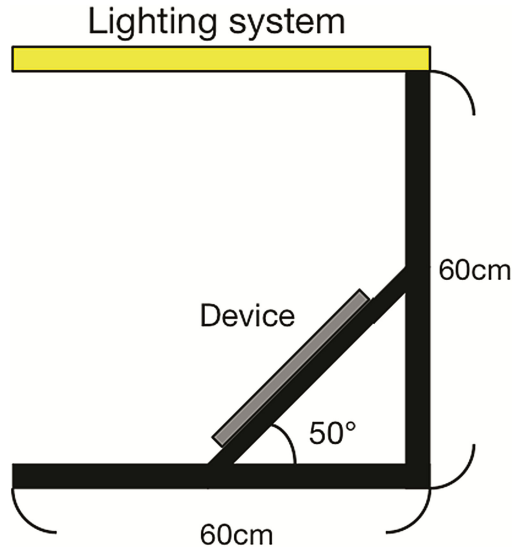


Fig. 2. Outline of the compartment

2.3 Task Design

The experimental task was for the subjects to read aloud a written text displayed on the devices. There were five words in English per line, and ten lines in each text passage (Fig. 3). The character font was 9 pt using a typeface of Times New Roman. The subjects began to read from the upper left in 15 s. We recorded the number of words that the subjects could read in 15 s as well as their viewing distance. After reading, the subjects evaluated the readability of the text. The subjects evaluated the readability of the devices using Analog Visual Scale, converted to between 0 and 100 points.

3 Results

We classified subjects as those who were 44 years old or younger as “Young”, those who were 45–64 years old as “Middle aged”, and those who were older than 65 years old as “Elderly”.

Below, we will refer to the Kindle Paperwhite as PW, the Kindle DX as DX and the paper as Paper in Figs. 4, 5 and 6.

Figure 4 shows the subjective evaluations of each device by the young group. Under low illuminance conditions, the younger subjects rated the Kindle Paperwhite higher than that of the Kindle DX. For conditions of more than 750 lx, the ratings Kindle Paperwhite were lower than Kindle DX.

Figure 5 shows the subjective evaluation of each device by the middle aged group. In lower conditions of illuminance this group evaluated the Kindle Paperwhite higher

BOY	CAT	CAP	DOG	BOOK
BOX	GREEN	OPEN	JAPAN	MILK
APPLE	CITY	SEVEN	CAR	FISH
MAP	PEN	MAN	BAG	DESK
STOP	HOTEL	PIANO	RED	HAND
JAPAN	MILK	APPLE	CAP	DESK
OPEN	RED	DOG	SEVEN	BOY
GREEN	MAP	CAT	HOTEL	MAN
STOP	CAR	BOOK	PIANO	CITY
PEN	HAND	FISH	BOX	BAG

Fig. 3. The used contents

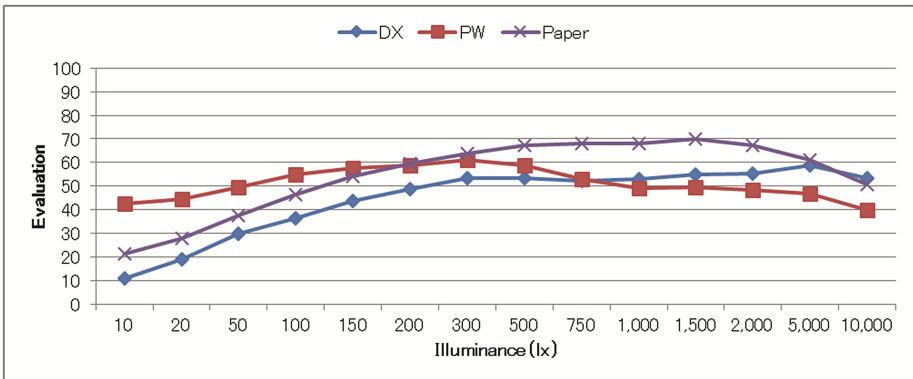


Fig. 4. Subjective evaluation of each device by young

than that of Kindle DX. Under the conditions of more than 750 lx, they rated the Kindle Paperwhite lower than the Kindle DX.

Figure 6 shows the subjective evaluation of each device by the elderly group. This last group also rated the Kindle Paperwhite higher than that of Kindle DX under low illuminance conditions. Under conditions of more than 500 lx, they ratings were almost the same.

4 Discussion

The younger group evaluate the Kindle Paperwhite higher in lower conditions of illumination. We found that there were no differences between the group evaluations of the Kindle Paperwhite in lower conditions of illuminance All of the evaluations were consistent in rating the Kindle DX above 10,000 lx.

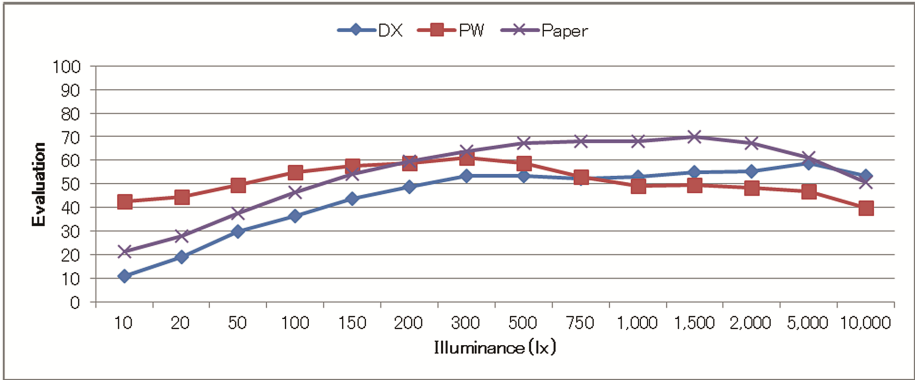


Fig. 5. Subjective evaluation of each device by middle aged

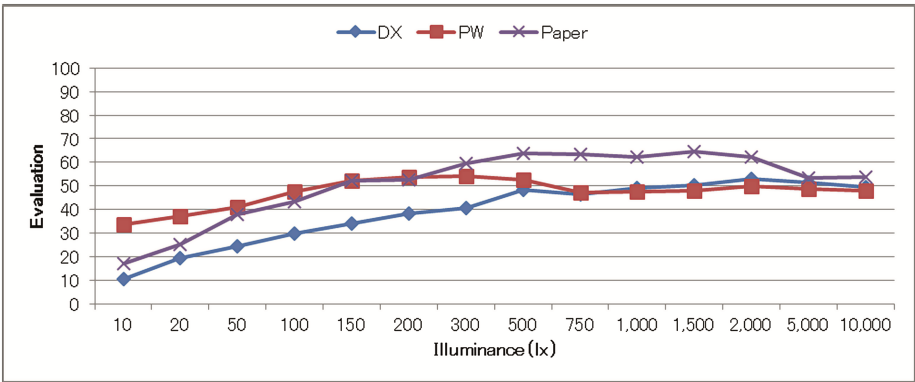


Fig. 6. Subjective evaluation of each device by elderly

The evaluations of Kindle Paperwhite was higher than that of the Kindle DX and paper text in the lower levels of illuminance.

One of the biggest advantages of the built-in light system is the sustained readability of e-paper under low conditions of illuminance. According to some previous studies, the use of the backlit LCD terminal is desired under low illuminance [3]. But according to our results, a built-in light system has a profound effect on readability under the low conditions of illuminance because the picture resolution and contrast ratio of the Kindle Paperwhite are superior. Since we used the Kindle Paperwhite at a configuration of maximum brightness, the subjects found the back light device much easier to read.

With an illuminance of more than 750 lx, the subjective evaluations of Kindle Paperwhite did decrease compared to the Kindle DX. The picture resolution and contrast ratio of the Kindle Paperwhite were superior, but Kindle Paperwhite has a light guide over the e-paper display. At higher levels of illuminance, the light guide appears to affect the evaluation of readability because it reflects light [4].

However, the subjective evaluation of the elderly was the best among the three age groups (clarify –do you mean for all levels? For which device??).

Some research has found that the elderly are comfortable with reading under conditions of [5], high illuminance. That would suggest that since those with high cloudiness have some blocking of the lenses for each cataract, the field of view becomes diffuse [6].

5 Conclusions

In this study, we carried out an experiment with a reading test to evaluate the readability of tablet devices and e-paper under various conditions of illuminance with subjects based on age. Our results show that significant differences exist between each device depending on age and illuminance. These results suggest that it is important to consider the age when developing such reading devices.

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