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The Influence of E-book Format and Reading Device on Users' Reading Experience: A Case Study of Graduate Students

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Abstract To explore the influence of e-book format and reading device on users' reading experience, this paper studied a group of graduate students' reading speed and comprehension. The participants were asked to read same length content from the same monograph chapter in both fixed layout format file (PDF) and fluid format file (EPUB) on four different reading devices: laptop, tablet, dedicated e-reader and smart phone. Their reading process, speed and comprehension were recorded and compared. Through the experiment and depth interviews, this study found that e-book format and reading devices have influence on reading speed and reading comprehension level. Generally speaking, people read EPUB files faster than PDF files. For smart phone, dedicated e-reader and tablet, participants' average reading comprehension is higher when reading EPUB file, while most participants read PDF file faster when they use laptops.

Keywords E-book format · Reading device · Reading speed · Comprehension

Introduction

E-book has been defined in various ways. Scholars believe it is a book-length publication in digital form, consisting of text, images, or both [9]. Sometimes it was defined as "an electronic version of a printed book [20]", although many

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e-books are without any printed equivalent. Most people agree that an e-book is intended to be read on electronic devices such as dedicated e-readers. On the whole, a more complete definition of an e-book should include electronic or digital content, and in-use features provided by reading device (hardware) and reading software [31].

At present, there are two main formats of e-books: fixed layout format and fluid format. Fixed layout is like the digital version of typesetting thus preserving the qualities of the printed page better [1]. Fluid format is ideal for text-based books and the books with small images embedded amongst the text. Thus different format is fit for different device; for instance fixed layout format is more suitable to big screen, while fluid layout is more suitable to small screen [26]. In the early stage, readers were still addicted to those digital texts presented almost the same as printed papers and didn't have much choice of reading devices, so fixed layout format(e.g. PDF) was widely adopted. But as the reading devices developed and the audience got used to reading on screen, fluid format (e.g. EPUB) began to be used more often, because it rearrange content according to the screen size of different devices better, thus readers can read it on any device and adjust the font size and style to fit their reading preferences [22].

Different e-book formats not only have different functional characteristics, but also perform differently in different reading devices. This study attempts to explore the user experience in fixed layout format and fluid format when reading on different devices.

Literature Review and Research Questions

The current studies on e-books mostly focus on the awareness, usage and attitude towards e-books [32], as well as comparison to printed books [25]. As for e-book reading devices, many empirical studies have been made to investigate user experience of a specific e-book device, or to compare functionalities between different devices. However, the research on e-book format's displaying effect on different devices is rare. In most existing studies, e-book format has been considered as a technical issue, rather than a factor that influences user's reading experience.

E-book Format

Widely used e-books formats include PDF, HTML, Mobi, and EPUB. Each file format has its advantages and weaknesses; different formats display text and graphics in different ways thus providing different reading experience. Most researchers agree that one of the biggest barriers to the acceptance of e-reader devices is the multiplicity of formats. The lack of standard e-book formatting is a critical issue for e-books' adoption [3]. Foasberg [7] pointed out that the format also caused many difficulties to libraries in lending e-reader to students.

PDF and EPUB are the representatives of fixed layout format and fluid format, and a number of studies have made research towards the two specific formats. PDF is one of the most popular e-book formats [30]. Because the format was developed

to provide a platform-independent means of displaying and exchanging fixed-layout documents, PDF files are supported by almost all modern e-book readers, tablets, PCs, laptops and smart phones. The fixity made PDF widely accepted as a digital archiving format [24]. However, some studies also suggested that PDF is not an ideal format for on-screen reading. Because PDF format is designed to reproduce fixed-layout pages, re-flowing text to fit mobile device and e-book reader screens can be problems [11]. Mallett [17] noted that Sony Reader and iPod Touch did a poor job of supporting PDFs, the documents were displayed at a very small size and the words were sometimes jumbled.

EPUB, a free and open e-book standard created by the International Digital Publishing Forum (IDPF) [14], is the distribution and interchange format standard for digital publications and documents. EPUB employs real-time flowable text so people can read it on any e-reader [22]. That has made EPUB the favoured file format in terms of readability of textual information [16]. And it is more suitable for scholarly requirements than the PDF format [23]. Although EPUB is an industry standard, it is not yet fully supported by all of the e-book reading devices [18, 33]. For example, Mobi and KF8, the two file formats of Amazon, both are incompatible with the EPUB standards [18]. An experiment study conducted by Schomisch et al. [23] showed that EPUB format displays text and tables better than formulas and figures in scholarly content. Moreover, Chinese EPUB e-books usually encounter more problems in typography, such as alignment, text-indent in the first line of paragraph and line spacing [34].

As PDF and EPUB both have their own advantages and disadvantages, an alternative solution that to combine these two formats has emerged [13]. In May 2013, General Administration of Press and Publication of China promulgated an industry standard called The Presentation Format of Content of the Digital Reading Devices, which adopted a format combined fixed layout format and fluid format [8, 26].

E-book Reading Devices

E-books can only be read via reading devices, and different reading devices support different e-books format. PC, e-reader, smartphone and tablet are the primary devices for e-book reading. The study of e-book reading on reading devices is also a hot topic for researchers and practionars.

Over the past 15 years, the relevant studies have emphasized on hardware and software characteristics. And lots of research works have been done to explain electronic device usage based upon the technology acceptance model. Some researchers found that price is the greatest barrier to e-reader adoption [7, 21]. And other studies suggested that portability [6], storage [7], special functions (such as text-to-speech) [7, 10], and compatibility [15] are important for users to accept e-reader. Schomisch et al. [23, 28] found that, e-readers functionalities that fit into the academic workflow, including non-linear reading, bookmarking, commenting, extracting text or the integration of non-textual elements, must be supported to gain increased acceptance by academic readers.

Different reading devices provide different reading experiences (Mainz [29]).Researchers conducted a lot of empirical researches about college students' reading behavior based on different reading devices. Pattuelli and Rabina [4] found that e-readers could enhance the students' reading experience because of its portability and convenience, by investigating the use of the Kindle 2 among graduate students of library and information science (LIS). However Hearn and McCaslin [12] did not find any evidence that the use of Kindle 2 would significantly improve the reading achievement and attitudes of college students. As for the purpose of using reading devices, leisure reading is the main purpose, such as for reading fiction, but not in academic setting [3, 19].

According to previous studies, we know that as two distinct e-book formats, fixed format and fluid format perform differently on different devices, and the formats can also affect the acceptance and use of e-book reading content and devices. But how reading experience can be affected by e-book format? Which format performs better on what kind of device? To understand how e-book format and device influence user's reading speed and comprehension, a comparative study between different formats' performance on different reading devices need to be done.

Methodology

The research employed a two phases reading experiment to evaluate the reading experience. In the experiment, the reading experience was evaluated by individual's reading speed and comprehension.

Formats

PDF is a representative format of fixed layout, while EPUB is a typical example of a fluid layout, and they are two of the most widely used formats in e-books. Therefore, PDF and EPUB were chosen to test e-book formats in this study.

Devices

Four e-book reading devices were compared in this study: laptop, tablet, smart phone and dedicated e-book reader. These four devices are most commonly used for e-book reading and they have comparable characteristics [21]. Among them, the

Table 1 Characteristics of the four devices

Device	Model	Screen size (inch)	Display technology	Colour/grayscale
Laptop	Dell insprion N4020	14	LED	Colour
Tablet	iPad 3	9.7	Retina	Colour
Smart phone	iphone 4 s	3.5	Retina	Colour
e-book reader	Kindle Paperwhite	6	e-ink	Grayscale

main differences considered are screen size, display technology and display colour (see Table 1).

Content

The experiment used one chapter from a scholarly monograph titled *The Management of Digital Publishing Industry* to test the participants' reading experience; the book was published in 2014 in Chinese language. The texts used for testing are all of the same length (2500–2550 Chinese characters), from the same chapter and without any figures and tables. Considering Chinese is the native language for participants, and it is possible that the English level of each participants are different, the experiment used Chinese text to avoid language interference. As all of the participants involved in this research majored in publishing studies, they were presumed to have basic knowledge of the content but not in details.

Participants

15 participants took part in the experiment and they were all first-year graduate students majored in publishing study from Wuhan University. 4 of them are male and the other 11 are female. For all the participants, it was their first time to read the book chapter.

Tasks

The whole experiment consisted of two phases. Phase 1 was designed to test reading speed while in phase 2, the participants' reading comprehension was tested.

Phase 1

In order to compare the influence of formats on reading speed, the participants were asked to read texts in PDF and EPUB successively on each different device. Phase 1 consisted of three steps:

- Step 1: Each participant read a paragraph of a book chapter in PDF format without time limitation or any instruction. When the participant finished reading, he or she would inform the research assistant, and the assistant recorded how long the reading took.
- Step 2: The participant was asked to read another paragraph of the same chapter in EPUB format on the same device; the time that he or she spent on finishing reading was recorded. In order to make the result comparable, the paragraphs we selected for the participant to read have the similar length.
- Step 3: The participant was required to repeat the first two steps but the reading device was changed to another one and the reading material was changed to other paragraphs from the same book chapter.

In this way, smart phone, e-reader, tablet and laptop were tested to display two different formats one by one. The time taken in each test was recorded for purposes of comparison.

Phase 2

In order to compare the influence of formats on readers' comprehension in different reading devices, the participants were asked to read texts in PDF and EPUB respectively on each different device, and then answer questions based on the text they just read. Phase 2 consists of three steps too:

- Step 1: Each participant was required to read a paragraph of the book chapter in PDF format within 5 min. And then the participant was asked to complete a test; the test included five questions related to the content that they just read.
- Step 2: The same participant was asked to read another paragraph of the same chapter in EPUB format on the same device, and then take another test which also contains five questions related to the content. In order to make the result comparable, the paragraphs we selected for the participant to read were of a similar length.
- Step 3: The participant was required to repeat the first two steps but the reading device was changed to another one.

That is to say, for each participant, smart phone, e-reader, tablet and laptop were tested to display two different formats one by one. The number of correct answers to the questions was counted as metric for valuating reading comprehension of each participant.

In order to further explore the users' reading preference for different formats on different reading devices, one-on-one depth interviews were conducted after the experiment.

Evaluation Technique and Measures

When the reading material was given, reading speed can be interpreted as the time a reader spending on finishing reading the material. Suppose the document format influences reading speed, when we tests the same participant's reading speed on different format with the same device, the result should be different. And assumed the reading device can affect reading speed, the same participants will spend different time in reading the same file format document on different reading devices.

The reading comprehension can be measured by the accuracy of answering in the reading-content-based questionnaire. With the same reading device, if most readers provided more correct answers when he or she read PDF than read EPUB, we could speculate that PDF is more suitable for such device, otherwise, EPUB is more suitable. For cross check, with the same document format, we could compare participants' comprehension on different reading devices.

Result and Discussion

Reading Speed

The results indicated that the majority of the participants read EPUB document much quicker than reading PDF document no matter which devices they used. Figure 1 shows that 13 participants (86.7 %) read EPUB document quicker than PDF with iPhone and Kindle. With iPad, 9 participants (60 %) read EPUB faster than PDF. In the case of laptop, the reading speed difference was not significant.

Some previous studies seemed to demonstrate that the screen size might be one of the factors influencing reading speed [2, 27], which may partly attribute to spending less time in page turning movement [5]. However, our experiment confirmed that not only screen size, but also file format will affect reading speed. For PDF format file, participants seemed read faster on larger screen than the small ones. However, when an EPUB file is used,our experiment showed that there is no significant influence of screen size on reading speed (please see Table 2).

We suggest that the possible reason might be an EPUB file could automatically rearrange the content to fit different screen. By contrast, the layout of a PDF page has been fixed, so on a relatively small screen like a mobile phone, the type size becomes small which may not easy to read.

Reading Comprehension

As discussed before, the number of correct answers showed the level of comprehension. The experiment indicated that on iPhone, 11 (73.3 %) participants got higher score when reading EPUB. Only 2 (13.3 %) participants did better when reading PDF, and the rest 2 (13.3 %) participants had the same score. On laptops, 8

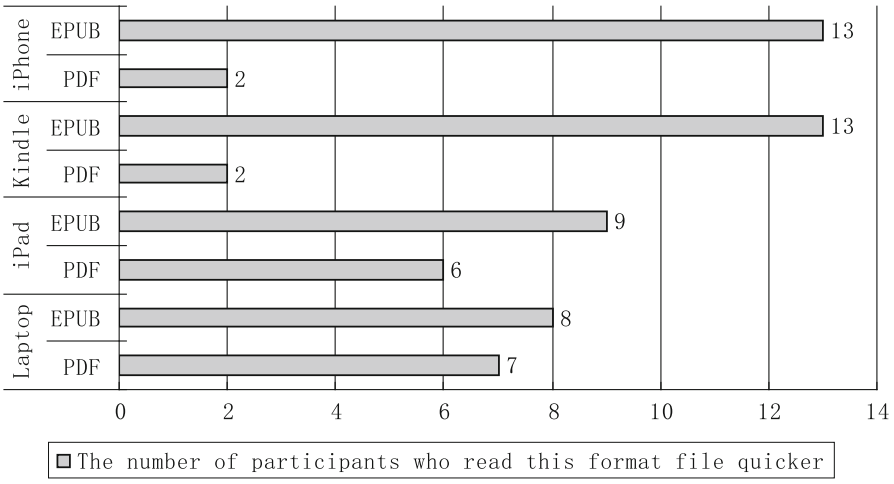

Fig. 1 Reading speed comparison of the two formats on each reading device

Table 2 Device and format influence on reading speed

Device	Laptop	iPad	Kindle	iPhone
PDF	736	650	642	582
EPUB	749	684	755	697

Note: N = characters/minute

(53.3 %) participants had a higher correct rate when reading PDF, 4(26.7 %) participants had a higher accuracy in EPUB reading, and the rest 3(20 %) participants got the same score no matter what type of format they read. There is no significant difference in accuracy between reading two formats on both Kindle and iPad (see Fig. 2).

When comparing the same participant's reading speed and comprehension between two formats on different devices, we can see the matching suitability of two e-book formats on four individual devices. Suppose more participants read EPUB file faster and understand the content better (got higher correct answer rate in this case) on iPhone, we can say that EPUB format has better displaying effect on iPhone. Figure 3 shows that EPUB displays better on both iPhone and Kindle: there were 11 who read quicker and got higher accuracy with EPUB on iPhone, and 9 participants read quicker and got higher score with EPUB on Kindle. While, the experiment showed PDF file matches iPad and laptop better, but not significant better.

Layout Preference

All the 15 participants were asked to elaborate on the layout design details that they like or dislike and to explain which details are more important. Specifically, the participants were required to compare the importance of 7 factors of e-book layout.

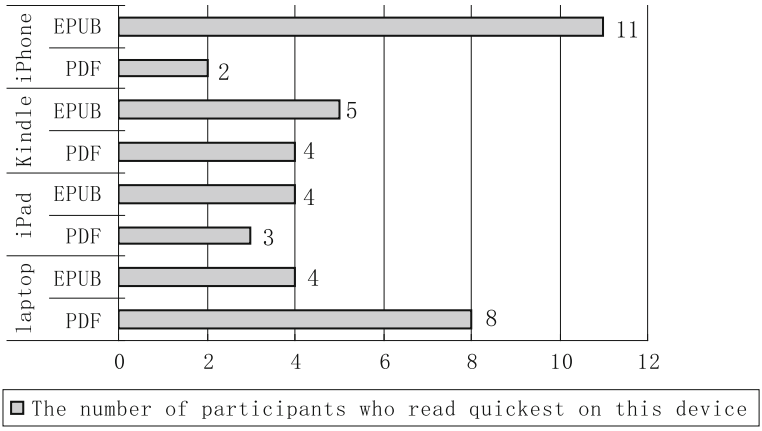

Fig. 2 Reading comprehension level comparison of the two formats on each reading device

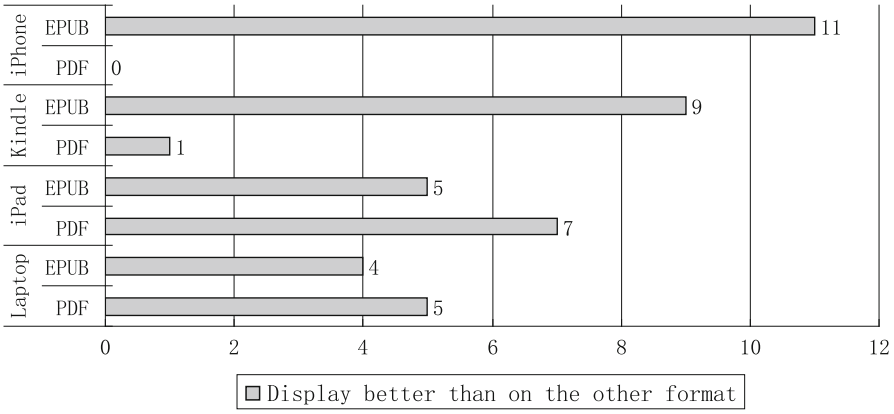

Fig. 3 Matching suitability of the two formats on each reading device

The 7 aspects are (1) typeface, (2) type size, (3) margin space, (4) paragraph alignment, (5) background, (6) line and paragraph space, (7) footnote and endnote.

For EPUB format (see Fig. 4), most participants thought the typeface and background design are important for faster reading and easier understanding. By contrast, no one agreed that the type size is an important influencing factor for reading EPUB. This is because an EPUB file could automatically rearrange the content to fit a different screen.

As for PDF format (see Fig. 5), compared with EPUB, the difference between the capabilities of the devices played a more important role in influencing reading experience. On a laptop, typeface, and paragraph alignment are the main influencing factors. On a Kindle, the space between line and paragraph is more important. On small screens such as iPhone, the type size affects reading a lot.

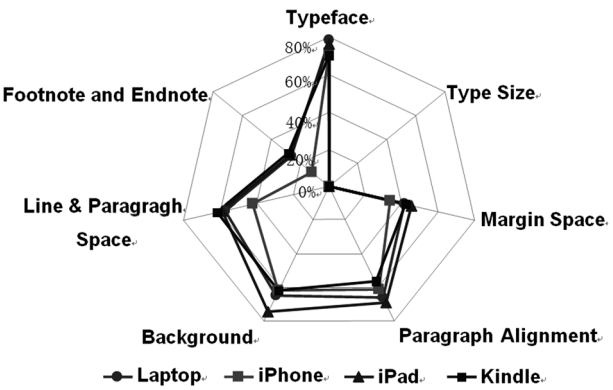

Fig. 4 Readers' layout preference details for EPUB format on four devices

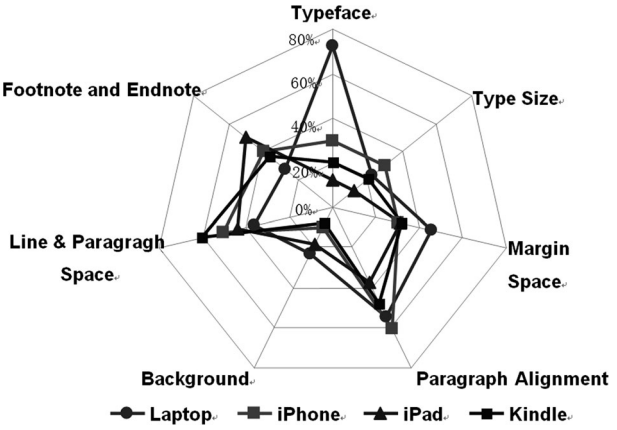

Fig. 5 Readers' layout preference details for PDF format on four devices

Conclusion and Limitation

As the study shows, e-book format and reading devices are the two principal influence factors that affect user reading experience. Generally speaking, people read EPUB file faster than reading PDF file, no matter what device they use. For smart phone, e-reader and tablet, participants' average reading comprehension is higher when reading EPUB, while for laptop, users feel that PDF file is easier for reading and understanding. The study proves that fluid format file is more suitable for displaying on smart phones and on dedicated e-readers. Bigger screen devices such as laptop and tablet are more suitable for displaying fixed layout format file rather than fluid format file.

The limitation of this study mainly lies in two aspects: firstly, the study only focuses on the scholarly content in Chinese texts, and the research participants are all post graduates majored the same subject. In future, we shall expand the size and the representativeness of the sample and change the content into non-scholarly texts in English language to make the study result comparable. The second aspect is that both experimental method and one-on-one depth interview approach have their own limitation when being used for the study of reading. In future studies, new research approach such as eye tracking technology and weblog analysis method should be applied.

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References

1. Adobe. Tagged PDF. http://help.adobe.com/en_US/FrameMaker/9.0/Using/WS8D54C9D2-A2D2-4eeb-8C18-38BD78D05943.html.

2. Bridgeman B, Lennon ML, Jackenthal A. Effects of screen size, screen resolution, and display rate on computer-based test performance. 2001. https://www.ets.org/Media/Research/pdf/RR-01-23-Bridgeman.pdf(2015-08-02).
3. Clark DT, Goodwin SP, Samuelson T, Coker C. A qualitative assessment of the Kindle e-book reader: results from initial focus groups. Perform Meas Metr. 2008;9(2):118–29.
4. Cristina Pattuelli M, Rabina D. Forms, effects, function: LIS students' attitudes towards portable e-book readers. Aslib Proc New Inf Perspect. 2010;62(3):228–44.
5. Dyson MC, Haselgrove M. The influence of reading speed and line length on the effectiveness of reading from screen. Int J Hum Comput Stud. 2001;54:585–612.
6. Fidler R. Using e-readers to explore some new media myths. Nieman Reports. 2008. http://www.nieman.harvard.edu/reports/article/100686/Using-E-Readers-to-Explore-Some-New-Media-Myths.aspx(2014-04-05).
7. Foasberg NM. Adoption of E-Book readers among college students: a Survey. Inf Technol Libr. 2011;9:108–28.
8. Founder Apabi Technology Limited. CEBX Became the Technological Base of Industrial Standard. *The Presentation Format of Content of the Digital Reading Devices.* 2013. http://gw.apabi.com/news/1/2013/0329/653.html(2015-07-20).
9. Gardiner E, Musto RG. The electronic book. In: Suarez MF, Woudhuysen HR, editors. The Oxford companion to the book. Oxford: Oxford University Press; 2010. p. 164.
10. Guy Whitehouse. h. Logos. 2010;21(3–4):142–51.
11. Hardy MRB. The Mars project: PDF in XML. In: Proceedings of the 2007 ACM symposium on document engineering. New York: ACM Press; 2007. p. 161–170.
12. Hearn BJ, McCaslin T. Kindle II impact on reading achievement and attitude. 2010. http://edtech2.tennessee.edu/rite/2010/fr_hearn_rite_10.pdf(2013-12-23).
13. IDPF. EPUB 3 Fixed-Layout Document. 2012. http://www.idpf.org/epub/fxl/.
14. International Digital Publishing Forum (formerly Open eBook Forum). http://idpf.org/epub.
15. Lai J-Y, Chang C-Y. User attitudes toward dedicated e-book readers for reading: the effects of convenience, compatibility and media richness. Online Inf Rev. 2011;3(4):558–80.
16. Lenzi VB, Leporini B. Investigating an accessible and usable ePub book via VoiceOver: a case study. In: Holzinger A, et al., editors. SouthCHI 2013. 2013. p. 272–83. http://download.springer.com/static/pdf/472/chp%253A10.1007%252F978-3-642-39062-3_17.pdf?auth66=1415461089_021c0d29aaf4fcd7577c7ed7bf3a7b67&ext=.pdf(2014-10-23).
17. Mallett E. A screen too far? Findings from an e book reader pilot. Serials. 2010;23(2):140–4.
18. McIlroy T. Ebook formats are a mess—here's why. Learn Publ. 2012;25(4):247–50.
19. Meyer K. Follow reader: consumer attitudes toward e-book reading. 2010. http://radar.oreilly.com/2010/08/followreader-consumer-attitudes-toward-e-book-reading.html(2013-12-27).
20. Oxford Dictionaries. 2010. Oxford University Press. http://www.oxforddictionaries.com/us/definition/american_english/e-book. Accessed 2 Sept 2015.
21. Richardson JV Jr, Mahmood K. eBook readers: user satisfaction and usability issues. Library Hi Tech. 2012;30(1):170–85.
22. Robley C. EBooks 101: standard vs. fixed layout. 2012. http://blog.bookbaby.com/2012/07/ebooks-101-standard-vs-fixed-layout/(2013-10-17).
23. Schomisch S, Zens M, Mayr P. Are e-readers suitable tools for scholarly work? Results from a user test. Online Inf Rev. 2013;37(3):388–404.
24. Seadle M. PDF in 2109? Library Hi Tech. 2009;27(4):639–44.
25. Segal-Drori O, Korat O, Shamir A, Klein PS. Reading electronic and printed books with and without adult instruction: effects on emergent reading. Read Writ 2010;23(8):913–30.
26. Sina. Industrial standard analysis: the presentation format of content of the digital reading devices. 2013. http://cs.sina.com.cn/minisite/news/20130416l006.html(2014-05-17).
27. Stoop J, Kreutzer P, Kircz J. Reading and Learning from Screens versus Print: a study in changing habits: part 1—reading long information rich texts. New Library World. 2013;114(7/8):284–300.
28. Thayer A, Lee CP, Hwang LH, Sales H, Sen P, Dalal N. The imposition and superimposition of digital reading technology: the academic potential of e-readers. In: CHI 2011 session: reading & writing, May 7–12. 2011; p. 2917–26.
29. Universität Mainz. Reading a book versus a screen: different reading devices, different modes of reading? 2011. http://www.sciencedaily.com/releases/2011/10/111020094337.htm(2013-12-17).
30. Vasileiou M, Hartley R, Rowley J. An overview of the e-book marketplace. Online Inf Rev. 2009;33(1):173–92.

31. Vassiliou M, Rowley J. Progressing the definition of e-book. Library Hi Tech. 2008;26(3):355–68.
32. Wang S, Bai X. University students awareness, usage and attitude towards e-books: experience from China. J Acad Libr. 2016;42(3)247–58
33. Weissberg A. The identification of digital book content. Publ Res Q. 2008;24:255–60.
34. Xiang T. Research on the EPUB ebooks standards. Publ J. 2013;21(2):89–94.