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# Effects of touch screen mobile devices and e-book systems on students' reading performance: A usability evidence

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**Abstract:** The development of e-books is gradually changing the reading habits of mobile users as the mobile device market grows. This study conducts a user-centered experiment on the touchscreen mobile device and the desktop computer with two popular e-book systems. 48 Taiwanese college students are recruited to perform 10 experimental tasks for collecting the quantitative and qualitative data. The experimental results show the touchscreen mobile device is more intuitive for the students to read e-books than the desktop computer. But, interestingly, they prefer to read e-books page by page as reading a traditional physical book. Furthermore, students' reading performance on the touchscreen mobile device could be compromised by poor interface design (e.g. 'Memory Retrieval' and 'Search' functions) of an e-book system. Consequently, this study suggests that the 'virtual keyboard' on the touchscreen should be improved and incorporated into new generation touchscreen mobile devices to satisfy students' reading requirements. In addition, most students prefer to combine two or three options (e.g. 'Up/Down Page' with 'Drag and Scroll') to read e-books. Therefore, the e-book interface should be more effective, flexible, and adaptable for students to enhance their reading performance.

**Keywords:** Touchscreen, Mobile Device, E-book System, Interface Design, Reading Performance, Usability.

## 1. Introduction

As both 'ambient intelligence' and 'ubiquitous computing' grow and mature, mobile devices (or handy devices) such as smart phones, e-book readers, ultrabooks (laptops), and tablets have become the most desired and popular commercial products, [37, 38]. According to various marketing reports [12, 23, 31, 40], the number of mobile device users is with 10%-30% annual growth. For example, the worldwide smartphone market has an annual growth of 25.3% in the second quarter of 2014 [12, 40]. This is a fantastic outcome for manufacturers and product designers. Accordingly, the mobile device market is competitive and is filling with multifunctional mobile devices. Tablet mobile phones or phablets with a large touchscreen (and some with a small keyboard) are used as tablets as well as mobile phones [45]. In addition, a 'Transformer Pad' or 'Flip PC' is not only a laptop but also a tablet with a touchscreen and a keyboard [55]. Therefore, users can choose a specific model based on their requirements [46]. In other words, users can use their fingers on the touchscreen to enlarge (zoom in) the size of an image on an e-book, and can also use the keyboard to type a keyword to search for a specific topic of interest [5]. Because of the availability of touchscreen mobile devices, users have more options to choose from [58]. However, are these touchscreen mobile devices user-friendly? What types of input devices/instruments (e.g. a touchscreen, mouse, and keyboard) do the users prefer? Which one has a higher level of satisfaction for e-book readers (particularly for students)?

In addition, a trend has been noted in the development of mobile devices. That is, the development of e-books is gradually changing the reading habits of mobile users and the manner in which they retrieve information [26, 35, 52]. For example, in the United States, around one in four of all book-buyers purchase at least one e-book each month. Moreover, 31% of new books purchased are e-books, and 15% of the dollars spent on these books are for e-books [4]. Moreover, Grimshaw et al. (2007) show that students who use e-books and online dictionaries to assist them in reading have a significantly higher reading comprehension compared with those who read traditional paper documents and use a paper-based dictionary [17, 60]. Korat and Shamir (2008) investigate the effect of e-books on reading comprehension and reveal that integrating e-books into learning activities can improve students' reading ability [30].

Baki (2010) defines e-books as *'books, prepared to be read via computers that have some additional features besides traditional physical books such as visuals, sound effects and interactive links'* [3, 34]. E-books have several advantages over traditional physical books, including reduced physical size, potentially increased profits for authors, and easier search and access for readers [50, 59]. Additionally, e-books are easy to operate and can incorporate multimedia and hypermedia content (e.g. audio, images, video, and links) [34]. Consequently, certain universities in the United States have adopted e-books as their teaching texts, whereas some elementary schools in Japan teach students to complete their homework by using e-books [25, 37, 57]. However, can e-books meet students' demands for reading? Is reading an e-book the same as reading a traditional physical book [38, 58]?

Good interface design of e-books will facilitate students' reading, whereas poor interface design can disorient them [36]. This indicates that students might lose track of the location and directions when browsing or navigating poorly-designed e-books [47]. Wang and Yang (2014) reveal that interface design is much more critical for students' e-books [48, 56]. Interface design refers to what appears on the users' screen, how they view it, and how they manipulate it, and this has a great effect on usability. It is usually concerned with the presentation of content and students' control over the e-book [56]. However, few studies examine how interface design affects reading performance in touchscreen mobile devices with different e-book systems [24, 46]. In other words, do touchscreen mobile devices have a good user interaction for enabling the reading of e-books? These are the critical research issues for researchers to address.

To address these issues mentioned above, we conduct a user-centered experiment on e-books in this study. For our experiment, we choose the most famous touchscreen mobile device, i.e. iPad, and two popular e-book systems (apps), i.e. Zinio and MagV, due to their popularity and cross-platform attributes [37]. In subsequent sections, we first present a brief outline of relevant studies, including interface design for e-books and touchscreen mobile devices for reading. We then present the user-centered experiment, including the participants involved, the test scenarios, and the experimental tasks. We also present the quantitative and qualitative data obtained from the user-centered experiment, including the reading performance and subjective satisfaction. Next, the analysis of variance (ANOVA) [15] is used to explore the relationship between the operation devices and the e-book systems, and their interactions. Finally, discussions and students' recommendations are given for the touchscreen mobile devices and the e-book systems.

## 2. Literature review

In this section, we present a brief review of relevant studies, including interface design for e-books and touchscreen mobile devices for reading.

### 2.1 Interface design for e-books

The term e-books are defined as self-contained digital texts whose basic structure mimics traditional books, but are viewed on an electronic display [13]. E-books have the same key features as traditional physical books in several ways such as text, illustrations, and pages that can be turned [56]. E-books' enhancements, including read-aloud texts, animations, sound effects, videos, and interactive links distinguish them from traditional physical books [56, 63].

Wang and Yang (2014) indicate that general e-book design principles can be summarized into four categories: (1) multimedia design, (2) interface design, (3) learning design, and (4) cultural design. An ideal e-book should be designed by considering all the four principles [42, 56], particularly interface design that is critical for students' e-books [48]. De Jong and Bus (2004) also state that the key to the success of students' e-books lies in their interface and interactivity [11]. In addition, Daniel and Woody (2013) find that interactive reading functions in e-books can promote improved reading outcomes and satisfaction [10]. Huang et al.

(2012) reveal that interactive e-book reading can support personalized reading for digital natives to cultivate habits of reading on demand among students [18, 34].

Shin (2011) and Lee (2013) suggest that perceived ease of use, perceived usefulness, and perceived satisfaction are all significant factors to predict students' behavioral intention for using e-books [33, 49]. Additionally, perceived ease of use can positively impact satisfaction and perceived usefulness, which can increase students' behavioral intention. The higher the quality of an e-book system's functions, the more satisfaction students will take in using e-books as reading tools [34]. However, Kropman et al. (2004) conclude that user interfaces and text displays have to be improved before screen-based reading can be widely accepted as an alternative [8, 32]. Consequently, e-book designers should find a balance between interface interactivity and complexity. High interactivity is a common goal for multimedia designers, but it does not always improve students' reading or learning [56]. Increased interactivity raises the usability problem, which may distract attention and cause difficulties for students while reading e-books. Therefore, extreme caution should be taken for e-book designers to prevent potential negative effects of interactive functions on reading or learning [56].

### 2.2 Touchscreen mobile devices for reading

While the mouse and keyboard have traditionally been the major input devices/instruments for computers, rapid advances in interactive technology have led to the emergence of the touchscreen as a common input device/instrument [19], which can potentially replace the mouse and keyboard [18]. The touchscreen is a natural and intuitive way for users to interact with a mobile device [2].

As compared to desktop computers, mobile devices can be used to facilitate students' reading [6]. Students can direct interact with the displayed objects, rather than indirectly through a mouse-controlled cursor [7, 21]. Mobile reading experiences have been found to be effective as they also enable students to have a reading experience in an authentic learning environment rather than the traditional classroom [29, 51]. Furió et al. (2013) indicate that students prefer the touchscreen experience of an iPhone game to that of traditional computer-based learning games [16, 19].

In addition, Ardito et al. (2013) conduct an experiment combining multi-touch technology with a puzzle on a historical theme to promote student learning. Students can use moving, scaling, and rotating an object on a touchscreen to operate the historical puzzle [2, 19]. It not only increases students' interest in participating in an interactive learning activity, but also enhances students' learning motivation and learning satisfaction [16]. Hung et al. (2015) also suggest that the use of touchscreens in educational settings may assist students to actively engage in interactive learning activities [19].

As mentioned above, this study will focus on the effects of the touchscreen of mobile devices and the interface design of e-book systems on students' reading performance, which are the critical research issues to be addressed.

## 3. A user-centered experiment

In this study, we conduct a user-centered experiment on e-books to explore the relationship between the operation devices and the e-book systems. The procedure of the user-centered experiment is presented in this section, including the participants, the test scenarios, and the experimental tasks.

### 3.1 Participants

There are 53 participants involved in the experimental study, including five design experts and 48 Taiwanese college students. These participants are divided into three groups. Except for the first group, we recruit undergraduate and graduate students as they usually pay more attention to mobile devices and e-books than other age groups [37]. The first group consists of five design experts to conduct 10 experimental tasks (to be discussed in Section 3.3). These experts have at least 10 years of interface design experience and the relevant analytical experiences of human-computer interface. According to Nielsen (1993), the optimal number of evaluators or experts in a heuristic evaluation or experimental study is three to five, which can identify about 66 to 75 percent of the usability problems in the system interface [36, 41].

The second group has 24 participants with the average age of 22.8, who are asked to use the touchscreen mobile device to engage in 10 experimental tasks. The third group has 24 participants with the average age of 21.5, who are asked to test on the desktop computer by using a mouse and/or a keyboard. The 48 students in the second and third groups have experiences with touchscreen mobile devices and e-books, but they never use the Zinio and MagV e-book systems before. Moreover, they are heavy computer and mobile device users with more than 20 hours of computer use per week. As such, each student has equivalent abilities with touchscreen mobile devices and e-books. These 48 students are asked to perform the 10 experimental tasks, whose results are used as a basis to conduct quantitative and qualitative analyses (to be discussed in Section 4).

### 3.2 Test scenarios

In order to answer the research questions mentioned in the Introduction section (e.g. is the touchscreen mobile device more effective for students reading e-books?), we adopt the common used mobile device, i.e. the iPad tablet, in this study. The tablet is suitable and portable to read the text without zooming in and navigating around to have it perfectly positioned for reading [9]. In addition, the top tablet market share is iPad (26.9% in 2014 according to the IDC report [22, 23]). On the other hand, although tablets can be useful to businesses or reading, many professionals still require traditional desktop computers. The desktop computer is thus used as the 'control group' in comparison with the reading performance using the mobile device.

To collect quantitative and qualitative data for further analysis, we choose two popular e-book systems (apps): Zinio and MagV, due to their popularity and cross-platform attributes [37]. The Zinio system captures over 60% market share in digital magazine circulation [62], and it is a polished platform for digital magazine reading, which has apps for iOS, Android, Windows, and a desktop reader for Mac and PC. In contrast, MagV is one of the biggest online Chinese bookstores in Asia, particularly in Taiwan, Hong Kong, and China [39].

The Zinio and MagV e-book systems have different interface design and different ways of navigating and reading e-books, as shown in Figure 1. Therefore, we can examine the usability of the interface design of the two e-book systems and their reading performance in reading e-books. In addition, even with the same e-book system, the interface design on the mobile device is different from the desktop computer, as shown in Figure 2. This is mainly due to the use of different operating methods and instruments, e.g. a touchscreen, a mouse, or a keyboard. Consequently, four test scenarios, the Zinio e-book system on the mobile device (Mobile-Z), the MagV e-book system on the mobile device (Mobile-M), the Zinio e-book system on the desktop computer (Desktop-Z), and the MagV e-book system on the desktop computer (Desktop-M), are used in this study, as shown in Figure 1.

### 3.3 Experimental tasks

In this study, we use 10 experimental tasks to examine the usability of the operation devices (i.e. the touchscreen mobile device and the desktop computer with a mouse and/or a keyboard) and the e-book systems (i.e. Zinio and MagV). As shown in Table 1, these 10 experimental tasks are to be performed by 48 students when reading e-books. The five design experts in the first group then observe the performance of these students and form a focus group [36, 41] to discuss the primary operating methods (or ways) and the corresponding functions (or utilities) used by the 48 students. Then the five experts combine similar opinions and discard the minor ones, according to their expertise and experience. Table 1 shows the corresponding operating functions commonly used by the 48 students when engaging in the 10 experimental tasks. For example, when students are performing Task 1 (T1) 'Please find the AA article on the Content Page of the BB book, and point out the exact position', they commonly use the operating functions of 'Scale' and/or 'Drag Page' to complete the task.

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(a) Mobile-Z


(c) Desktop-Z


(b) Mobile-M


(d) Desktop-M

**Figure. 1.** The interface design of four test scenarios.


(a) Mobile-M


(b) Desktop-M

**Figure. 2.** The operating method and interface design of the MagV system.

**Table 1.** 10 experimental tasks and the corresponding operating functions

| Task No. | Task Description | Corresponding Operating Functions |
|---|---|---|
| T1 | Please find the *AA* article on the Content Page of the *BB* book, and point out the exact position. | • Scale<br>• Drag Page |
| T2 | Please find the first page of the *AA* article, and point out the exact position. | • Content Page<br>• Drag and Scroll<br>• Up/Down Page |
| T3 | Please find the *CC* title in the *AA* article, and point out the exact position. | • Drag and Scroll<br>• Up/Down Page |
| T4 | Please read the *DD* point of suggestions aloud in the *CC* paragraph, and answer the *EE* question. | • Scale<br>• Drag Page |
| T5 | Please return to the initial model, and choose another *FF* book. | • Content Page<br>• Choose Book |
| T6 | Please browse the Content Page of the *FF* book, find the *GG* title, and point out the exact position. | • Scale<br>• Drag Page |
| T7 | Please find the first page of the *HH* article, which contains the *GG* title. | • Content Page<br>• Drag and Scroll<br>• Up/Down Page |
| T8 | Please answer the *II* question aloud in the *JJ* paragraph of the *HH* article. | • Scale<br>• Drag Page<br>• Drag and Scroll<br>• Up/Down Page |
| T9 | Please return to the *BB* book from the *FF* book, and find the first page of the *AA* article. | • Content Page<br>• Choose Book<br>• Memory Retrieval |
| T10 | Please find the *KK* paragraph in the *AA* article, and answer the *LL* question. | • Scale<br>• Up/Down Page |

* Each symbol *AA, BB,…, LL* represents a specific text individually.

### 3.4 Procedure of the user-centered experiment

We record the entire experimental session on video while the students are engaging in the 10 experimental tasks. We could use the video recordings as backup to notes. As such, we can go back and review the recordings according to the 'retrospective testing' method [5, 41]. Based on the retrospective testing, we can obtain the qualitative data and the operation details when students are reading e-books. After the usability assessment, a semi structured questionnaire is used to collect information pertaining to students' 'subjective satisfaction' of reading e-books. The procedure of this experiment is summarized in the following 8 steps:

Step 1: Divide 53 participants into three groups.

Step 2: Conduct 10 experimental tasks by five interface design experts of the first group.

Step 3: Perform the 10 experimental tasks by 48 students in Groups 2 and 3. The 24 students in Group 2 test two e-book systems by using the touchscreen mobile device (Mobile-Z, and Mobile-M). These students are randomly assigned to test the Zinio or MagV e-book system. Before the test, they have 5 to 10 minutes to free practice and operate the e-book system, and then perform the 10 experimental tasks.

Step 4: Take a short break (about 10 to 15 minutes) after the test, and then test the other system (MagV or Zinio), depending on which is taken first, until the 10 experimental tasks are completed. The 24 students in Group 3 are asked to test on the desktop computer by using a mouse and/or a keyboard (Desktop-Z, and Desktop-M), and follows the same procedure as Group 2.

Step 5: Record the entire experimental session on video, including the operation time and errors occurred during the 10 experimental tasks.

Step 6: Distribute the semistructured questionnaire to collect quantitative (i.e. the students' subjective satisfaction assessment about the e-book systems) and qualitative data (i.e. the students' suggestions regarding devices and e-book systems).

Step 7: Analyze the experimental data, including the operation time, error frequency, and subjective satisfaction.

Step 8: Discuss and conclude.

## 4. Results and analyses

In this section, we present the results of the quantitative and qualitative analysis, including the operation time, error frequency, and subjective satisfaction.

### 4.1 Analysis of operation time and error frequency

Table 2 shows the average operation time and error frequency of the 48 students when they perform the 10 experimental tasks. In Table 2, T1 to T10 in the second and ninth rows represent Task 1 to Task 10, respectively. Additionally, Mobile-Z, Mobile-M, Desktop-Z, and Desktop-M in the first column indicate the four test scenarios in this study.

**Operation time.** As shown in Table 2, the operation time of the mobile device (490.23 seconds) is faster than the desktop computer (789.31 seconds). In addition, the operation time of Mobile-Z (229.02 seconds) is the fastest for completing the whole tasks, followed by those of Mobile-M (261.21 seconds), Desktop-Z (360.64 seconds), and Desktop-M (428.67 seconds). This result suggests that using the mobile device (using the touchscreen) to read e-books is easier than the desktop computer (with a mouse and/or a keyboard). Moreover, with the same devices/instruments, using the Zinio e-book system is more efficient than MagV (Mobile-Z (229.02 seconds) < Mobile-M (261.21 seconds), and Desktop-Z (360.64 seconds) < Desktop-M (428.67 seconds)). The result indicates that the interface design of the Zinio e-book system has a better usability.

**Error frequency.** In this study, an error is defined as any action that does not reach the desired goal [41]. We count the number of such actions made by the students when performing the 10 experimental tasks. The error frequency is the average of the errors made by the students in a specific task. From Table 2, the error frequency of the mobile device (4.04 times) is less than the desktop computer (10.45 times) for completing the 10 tasks, particularly the Mobile-Z (1.87 times) being the lowest, followed by those of Mobile-M (2.17 times), Desktop-M (4.76 times), and Desktop-Z (5.69 times). The result indicates that using the mobile device results in fewer errors.

In addition to the operation time, using the Zinio e-book system with the touchscreen also results in a lower error frequency than MagV (Mobile-Z (1.87 times) < Mobile-M (2.17 times)). However, the Desktop-Z (5.69 times) has a slightly higher error frequency than Desktop-M (4.76 times), although Desktop-Z (360.64 seconds) has less operation time than Desktop-M (428.67 seconds).

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**Table 2.** Result of the operation time and error frequency

| Operation Time (second) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | Total | |
| Mobile-Z | 12.42 | 21.22 | 16.22 | 8.17 | 22.64 | 8.63 | 43.98 | 28.83 | 37.70 | 29.21 | 229.02 | 490.23 |
| Mobile-M | 24.65 | 28.42 | 5.88 | 3.33 | 22.78 | 8.16 | 104.94 | 37.44 | 19.63 | 5.98 | 261.21 | |
| Desktop-Z | 11.83 | 20.62 | 25.89 | 27.29 | 41.76 | 29.88 | 95.92 | 58.62 | 24.98 | 23.85 | 360.64 | 789.31 |
| Desktop-M | 19.05 | 73.74 | 27.97 | 30.96 | 86.11 | 27.98 | 72.99 | 32.63 | 17.03 | 40.21 | 428.67 | |
| Total | 67.95 | 144.00 | 75.96 | 69.75 | 173.29 | 74.65 | 317.83 | 157.52 | 99.34 | 99.25 | 1279.54 | 1279.54 |
| Error Frequency | | | | | | | | | | | | |
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | Total | |
| Mobile-Z | 0.17 | 0.13 | 0.04 | 0.00 | 0.33 | 0.00 | 0.79 | 0.08 | 0.29 | 0.04 | 1.87 | 4.04 |
| Mobile-M | 0.33 | 0.33 | 0.00 | 0.00 | 0.25 | 0.04 | 0.92 | 0.13 | 0.13 | 0.04 | 2.17 | |
| Desktop-Z | 0.04 | 0.25 | 0.38 | 0.21 | 1.13 | 0.42 | 1.83 | 1.13 | 0.13 | 0.17 | 5.69 | 10.45 |
| Desktop-M | 0.17 | 1.25 | 0.33 | 0.17 | 0.96 | 0.08 | 0.92 | 0.21 | 0.25 | 0.42 | 4.76 | |
| Total | 0.71 | 1.96 | 0.75 | 0.38 | 2.67 | 0.54 | 4.46 | 1.55 | 0.80 | 0.67 | 14.49 | 14.49 |

### 4.2 Analysis of variance (ANOVA) for operation devices (mobile and desktop) and e-book systems (Zinio and MagV)

For further analysis, we use the two-way ANOVA [15] to explore the relationship between the independent variables (the operation device and the e-book system) and their interactions. For example, is there any interaction between the operation device and the e-book system on the dependent variables (the operation time and the error frequency)? In other words, whether a ‘statistically significant interaction’ exists in mobile (or desktop) and Zinio (or MagV) regarding the operation time (or the error frequency) when students are performing some specific tasks? Moreover, is the mobile device more effective (faster and few errors) than the desktop computer for reading e-books?

**Two-way ANOVA to examine the significant interaction.** The two-way ANOVA is conducted to examine the effect of the operation device and the e-book system on the operation time and the error frequency. Table 3 shows the result. The third row of Table 3 shows that statistically significant interactions exist in T2 ($F=26.48$, $p<0.001$), T7 ($F=10.40$, $p<0.01$), T8 ($F=7.23$, $p<0.01$) and T10 ($F=13.85$, $p<0.001$), respectively, between the operation device and the e-book system on the operation time. The result suggests that no matter what the operation device is or the e-book system is, it will influence students’ efficiency performance on specific tasks (T2, T7, T8 and T10). In addition, the eighth row of Table 3 shows that T2 (F=6.79, p<0.05) and T8 (F=6.58, p<0.05) have the statistically significant interactions between the operation device and the e-book system on the error frequency. Figure 3 shows the ‘profile plot’, which is commonly used to examine the interaction of two variables. An interaction effect can usually be seen as the non-parallel lines or the crossed lines [14]. Moreover, if there is a statistically significant interaction, we need to further perform ‘simple main effects’. Alternately, if not, we should report ‘main effects’ [15] (to be discussed in the next sub-section).

**Main effect test and simple main effect test.** If there is no interaction between the operation device and the e-book system, we can test ‘main effects’ on the operation device or the e-book system to determine whether there is evidence of an effect of different treatments (e.g. the mobile or desktop, Zinio or MagV). According to the result of the two-way ANOVA shown in Table 3, T1 (F=4.52, p<0.05) or T9 (F=18.29, p<0.001) has a statistical significance of the ‘main effect’ on the e-book system, while T3 (F=8.82, p<0.01), T4 (F=42.11, p<0.001), T5 (F=11.53, p<0.001), T6 (F=28.23, p<0.001), or T9 (F=6.34, p<0.05) has the ‘main effect’ on the operation device. With further analysis, we find the strong evidence that using the Zinio e-book system to perform Task 1 is faster (12.12 seconds) than using the MagV e-book system (21.85 seconds), which is consistent with the result presented in Section 4.1. Additionally, for Task 3 to Task 6, the mobile device has less operation time and few errors (11.98 seconds and 0.08 times) than the desktop computer (37.23 seconds and 0.46 times). This result indicates that the touchscreen mobile device is more effective than the desktop computer with a mouse and/or a keyboard.

Simple main effects are used to examine why an interaction exists and what causes the interaction happened [15]. A simple main effect is a ‘main effect’ of one factor (e.g. the operation device) at a given level of a second factor (e.g. the e-book system). Table 4 shows the result of simple main effects in T2, T7, T8 and T10, respectively. The analysis of simple main effects shows that the Zinio e-book system (43.98 seconds) is significantly faster than the MagV e-book system (104.94 seconds) when the students use the mobile device to perform T7 (F=10.16, p<0.01), but contrarily the MagV e-book system (5.98 seconds) is significantly faster than the Zinio e-book system (29.21 seconds) when the students carry out T10 (F=23.25, p<0.001).

In addition, there is no difference between the operation devices when the students perform T2 on the Zinio e-book system (F=0.02, p=0.89>0.05), but the mobile device (28.42 seconds) is significantly faster than the desktop computer (73.74 seconds) when the students use the MagV e-book system (F=34.08, p<0.001). The further discussion will be presented in Section 5.

**Table 3.** Result of the two-way ANOVA (showing F values and the significant levels)

| (F value) | Operation Time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 |
| Device*System | 0.30 | 26.48*** | 1.35 | 1.40 | 3.31 | 0.03 | 10.40** | 7.23** | 2.77 | 13.85*** |
| Input Device | 0.46 | 25.13*** | 8.82** | 42.11*** | 11.53*** | 28.23*** | 0.59 | 3.77 | 6.34* | 7.36** |
| E-book System | 4.52* | 45.71*** | 0.60 | 0.03 | 3.36 | 0.09 | 2.14 | 1.82 | 18.29*** | 0.42 |

| (F value) | Error Frequency | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 |
| Device*System | 0.05 | 6.79* | 0.00 | 0.10 | 0.04 | 3.43 | 2.84 | 6.58* | 2.27 | 1.50 |
| Input Device | 2.48 | 11.75*** | 9.47** | 8.35** | 11.56*** | 5.13* | 2.84 | 9.07** | 0.05 | 5.98* |
| E-book System | 2.48 | 15.82*** | 0.15 | 0.10 | 0.32 | 2.08 | 1.64 | 5.49* | 0.05 | 1.50 |

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*p<0.05, **p<0.01, ***p<0.001

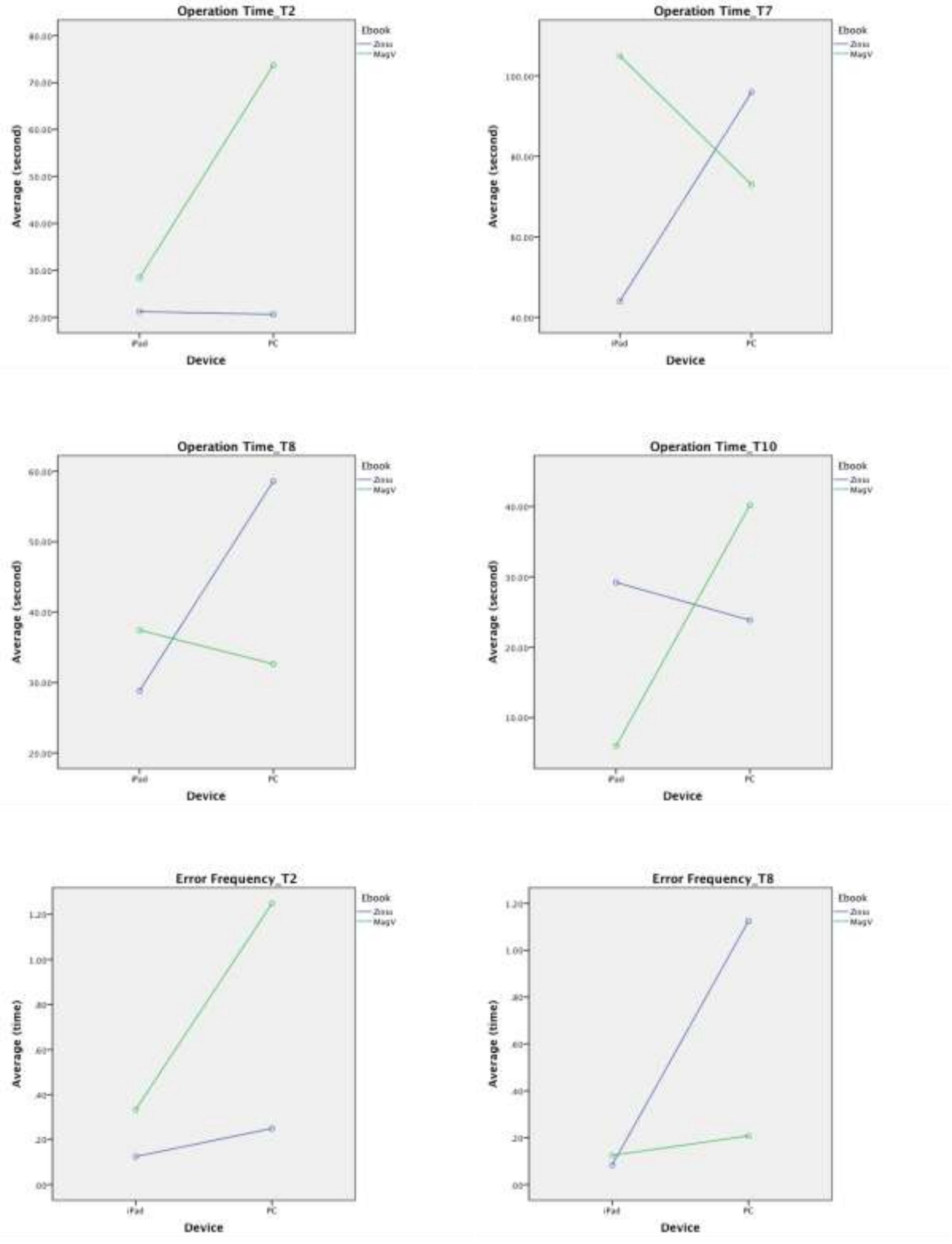


**Figure. 3.** Profile plots of T2, T7, T8 and T10

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**Table 4.** Result of simple main effects in T2, T7, T8 and T10

| | Factor B: E-book System | | | | |
|---|---|---|---|---|---|
| Factor A: Device | Task | Zinio | | MagV | F value |
| Mobile | T7 (Time) | 43.98 | < | 104.94 | 10.16** |
| | T10 (Time) | 29.21 | > | 5.98 | 23.25*** |
| Desktop | T2 (Time) | 20.62 | < | 73.74 | 46.10*** |
| | T8 (Time) | 58.62 | > | 32.63 | 5.98** |
| | T2 (Error) | 0.25 | < | 1.25 | 14.92*** |
| | T8 (Error) | 1.13 | > | 0.21 | 6.39** |
| | Factor B: Device | | | | |
| Factor A: E-book System | Task | Mobile | | Desktop | F value |
| Zinio | T7 (Time) | 43.98 | < | 95.92 | 12.78*** |
| | T8 (Time) | 28.83 | < | 58.62 | 7.98** |
| | T8 (Error) | 0.08 | < | 1.13 | 8.50** |
| MagV | T2 (Time) | 28.42 | < | 73.74 | 34.08*** |
| | T10 (Time) | 5.98 | < | 40.21 | 13.29*** |
| | T2 (Error) | 0.33 | < | 1.25 | 11.09** |

*p<0.05, **p<0.01, ***p<0.001

### 4.3 Analysis of subjective satisfaction assessment

Tractinsky et al. (2000) have found a strong correlation between the system aesthetics and its usability, which persists even after users have used the system [54]. In other words, aesthetic responses are closely related to usability (such as “a priori perception of ease of use”) [53, 54]. In addition, Yamamoto and Lambert (1994) find that aesthetically pleasing properties have a positive effect on users’ preferences of a system and their decision processes when they use the system [27, 28, 61].

**Subjective satisfaction assessment.** Based on the above discussions, we distribute the semistructured questionnaire to collect quantitative and qualitative data after the students complete the 10 experimental tasks. The students are asked to assess two questions about the interface design of the e-book system: *‘S1: how do you feel regarding the visual and aesthetical style of the interface design?’* and *‘S2: how do you feel regarding the operation (operating efficiency) of the interface design?’* A 5-point scale is adopted in the semistructured questionnaire, ranging from 1 (the lowest satisfaction) to 5 (the highest satisfaction).

Figure 4 shows the result of students’ subjective satisfaction assessment (S1 and S2). The result of S1 (i.e. aesthetics) suggests that there is a slight difference between the mobile device (iPad of 3.85) and the desktop device (PC of 3.75), and the same condition applies to the Zinio (3.90) and MagV (3.71) e-book systems. Among the four test scenarios, Mobile-Z is the highest (3.92) and Desktop-M is the lowest (3.63). The result of S2 (i.e. operation) shows that the Zinio e-book system has a higher degree of satisfaction (Mobile-Z of 3.88 and Desktop-Z of 3.67) than MagV (Mobile-M of 3.29 and Desktop-M of 3.08). For a further discussion, one-way ANOVA is conducted, as shown in the next sub-section.

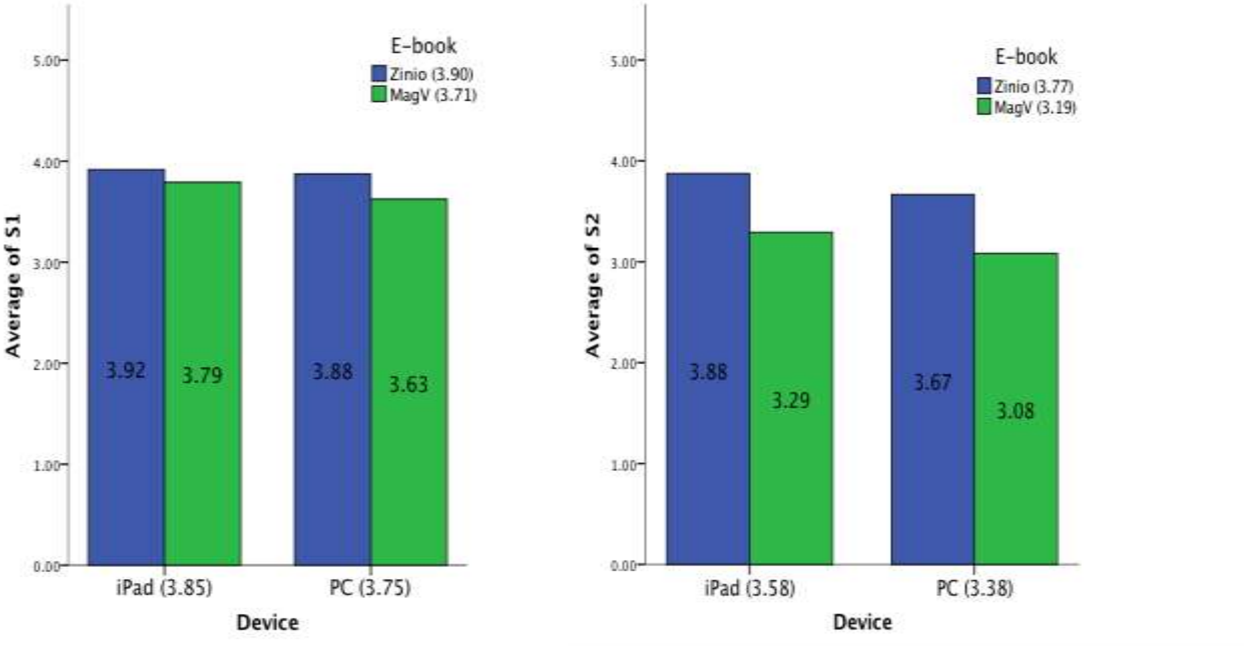


**Figure. 4.** Result of the subjective satisfaction assessment

**One-way ANOVA for the subjective satisfaction assessment.** Based on the above discussions, we distribute the semistructured questionnaire to collect quantitative and qualitative data after the students complete the experimental tasks. The students are asked to assess two questions about the interface design of the e-book system: *'S1: how do you feel regarding the visual and aesthetical style of the interface design?'* and *'S2: how do you feel regarding the operation (operating efficiency) of the interface design?'* A 5-point scale is adopted in the semistructured questionnaire, ranging from 1 (the lowest satisfaction) to 5 (the highest satisfaction).

Table 5 shows the result of multiple comparisons among the four test scenarios. From Table 5, three comparisons have significant differences in S2. They are Mobile-Z vs. Mobile-M (mean difference=0.59, p=0.04), Mobile-Z vs. Desktop-M (mean difference=0.80, p=0.01), and Desktop-Z vs. Desktop-M (mean difference=0.59, p=0.04), respectively. The result indicates that the interface design of the Zinio e-book system is more user-friendly and efficient (S2) as perceived by the students, although the visual and aesthetical style (S1) of Zinio is identical to that of MagV. This is also reflected by the operation time and the error frequency presented in Section 4.1.

**Table 5.** Result of multiple comparisons among the four test scenarios

| | | | S1 | | S2 | |
|---|---|---|---|---|---|---|
| Four Test Scenarios | | | Mean Difference | P | Mean Difference | P |
| Mobile-Z | vs. | Mobile-M | 0.13 | 0.58 | ***0.59**** | ***0.04*** |
| | | Desktop-Z | 0.04 | 0.85 | 0.21 | 0.45 |
| | | Desktop-M | 0.29 | 0.20 | ***0.80**** | ***0.01*** |
| Mobile-M | vs. | Desktop-Z | -0.09 | 0.71 | -0.38 | 0.17 |
| | | Desktop-M | 0.16 | 0.46 | 0.21 | 0.45 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Desktop-Z | vs. | Desktop-M | 0.25 | 0.27 | ***0.59**** | ***0.04*** |

## 5. Discussion

This study aims to examine whether the touchscreen mobile device and the e-book system can enhance students' reading performance. According to the analysis of operation time and error frequency obtained from the 48 students performing the 10 experimental tasks, using the touchscreen mobile device is faster and has fewer errors. The analysis also shows that it is more effective and intuitive for students to use the touchscreen, thus helping to prevent errors. In other words, the touchscreen mobile device is more effective than the desktop computer with a mouse and/or a keyboard [7, 19]. Because the touchscreen is intuitive as reading the traditional physical book, the students can drag/turn pages directly as compared to clicking the button (on the mouse) or pressing the Left/Right keys (on the keyboard) to the next page. Moreover, the interface design of the Zinio e-book system has a better usability than that of MagV, indicating that a good interface design of the e-book system makes reading easy and user-friendly [37]. These findings are similar to previous studies [2, 6, 10, 11, 32] that the touchscreen is a natural and intuitive way for facilitating students' reading. Furthermore, the success of e-books depends largely on their interface design and interactivity, which can improve reading outcomes and satisfaction.

However, according to the two-way ANOVA, there is no difference when the students perform T2 on the Zinio e-book system, but the mobile device is significantly faster than the desktop computer when the students use the MagV e-book system. With further analysis, the description of T2 is *'Please find the first page of the AA article, and point out the exact position'*, and their corresponding operating functions are 'Content Page', 'Drag and Scroll', and/or 'Up/Down Page'. It indicates that when the students perform T2 by using 'Content Page', 'Drag and Scroll', and/or 'Up/Down Page' functions, the reading performance of the Zinio e-book system on the desktop computer is the same as the mobile device, but it is significantly different when the MagV e-book system is used. In other words, the reading performance could be significantly different when using different operation devices and/or the e-book systems. This suggests that although the touchscreen mobile device is more effective than the desktop computer, the reading performance could be compromised by the poor interface design of the e-book system.

For another example, there is a significant difference when the students perform T7 on the Zinio e-book system and the MagV e-book system. The description of T7 is *'Please find the first page of the HH article, which contains the GG title'*, and their corresponding operating functions are 'Content Page', 'Drag and Scroll', and/or 'Up/Down Page'. This indicates that when students perform T7 by using 'Content Page', 'Drag and Scroll', and/or 'Up/Down Page' functions, their reading performance on the Zinio e-book system is significantly better than the MagV e-book system. In other words, the reading performance of the e-book system could depend largely on its user interface design.

In addition, it is interesting to note that Desktop-Z has a slightly higher error frequency than Desktop-M, although Desktop-Z has less operation time than Desktop-M. The result reveals that even though the students operate in the wrong way, it can be recovered faster if using Zinio e-book system on the desktop computer. To further compare these two e-book systems, we perform the correlation analysis to examine the relationship of operation time and error frequency. The result shows that there is a high positive correlation on the Zinio e-book system (Pearson's $r=0.736$, $p=0.015$), while the MagV e-book system has a very strong positive correlation (Pearson's $r=0.951$, $p=0.001$). The result also reflects that students may make few errors while using a system, but the critical issue is how easily the students can recover from the errors [5].

The analysis of the subjective satisfaction assessment result shows that the interface design of the Zinio e-book system is more user-friendly and efficient as perceived by the students, although the visual and aesthetical style of the Zinio e-book system is identical to that of MagV. This is also reflected by the operation time and the error frequency presented in Section 4.1. Additionally, it is worth noting that the students' psychological feelings are more heavily influenced by different e-book systems than by different devices, even though students' reading performance using the mobile device is significantly more effective than the desktop computer.

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In order to help e-book manufacturers and designers design a better user interface for an e-book system, we examine what a better way is for students to carry out a specific task when using its corresponding operating functions. According to the result of the two-way ANOVA, if there is a significant difference between the operation devices and/or the e-book systems, the better one (e.g. the mobile device or the Zinio e-book system) will get one point on the specific operating function, as shown in Table 6. Table 6 shows that the mobile device is better than the desktop computer for most of operating functions, except the 'Memory Retrieval' function. Moreover, the Zinio e-book system has operating advantages for the 'Content Page', 'Drag and Scroll', and 'Up/Down Page' functions, while the MagV e-book system is better for the 'Scale', 'Drag Page', 'Choose Book', and 'Memory Retrieval' functions. The result provides useful insights for e-book designers in designing an effective user interface that can best meet users' requirements. For example, e-book designers for the Zinio e-book system should enhance and/or modify the operating functions of 'Scale', 'Drag Page', 'Choose Book', and 'Memory Retrieval' if they want to have a more effective and efficient interface design. The e-book designers should take into account the cognitive learning/reading strategies [43] to enrich the learning/reading material by means of textual and pictorial externalizations, which are defined as annotations, such as underlining, highlighting, labeling, sketching, and taking notes [44, 64].

For another example, the desktop computer is superior for the 'Memory Retrieval' function than the touchscreen mobile device. This is because students can use the keyboard to easily type a keyword to search for a specific topic, thus having a better performance for the 'Search' function. Although students can directly type a keyword on the touchscreen (usually using the 'virtual' keyboard), there is a lack of feeling when typing/pressing the keys/buttons on the touchscreen. Furthermore, students can use both hands to type a keyword on the 'physical' keyboard, but use only one finger (or at most two fingers) on the 'virtual' keyboard. As such, the new input device or operating way, such as 'smart keyboard', 'force touch', or '3D touch' [1], should be taken into consideration for the new generation touchscreen mobile devices to enhance students' reading performance and satisfy their reading requirements.

For further discussions, we conduct the retrospective testing [41] to identify differences between the operation time and the error frequency when students are engaging in the experimental tasks. According to the observations and video coding, for example, three options (operating functions) are chosen when the students perform T2. The students can use only the 'Content Page' to find the first page of the AA article; alternatively, they can use 'Drag and Scroll' or 'Up/Down Page' to achieve it. They could also combine these options. Table 7 shows the percentage of the options chosen by the students. Most students prefer to combine two or three options (e.g. 'Up/Down Page' with 'Drag and Scroll') to read an e-book. In addition, the students (except in their use of Desktop-Z) also like to navigate the article (i.e. page by page) in a similar manner to reading a traditional physical book.

**Table 6.** Performance comparison for the operating functions

| Operating Function | Operation Device | | E-book System | |
|---|---|---|---|---|
| | Mobile | Desktop | Zinio | MagV |
| Scale | 𝍸𝍷𝍷𝍷 | | 𝍷 | 𝍷𝍷𝍷 |
| Drag Page | 𝍸𝍷 | | 𝍷 | 𝍷𝍷 |
| Content Page | 𝍸𝍷 | 𝍷 | 𝍷𝍷𝍷𝍷 | 𝍷 |
| Drag and Scroll | 𝍸𝍷𝍷𝍷 | | 𝍷𝍷𝍷𝍷 | 𝍷𝍷 |
| Up/Down Page | 𝍸𝍸 | | 𝍷𝍷𝍷𝍷 | 𝍷𝍷𝍷 |
| Choose Book | 𝍷𝍷 | 𝍷 | | 𝍷 |
| Memory Retrieval | | 𝍷 | | 𝍷 |

**Table 7.** Percentage of the options chosen by students when performing T2

| | Options / Operating Functions | | | |
|---|---|---|---|---|
| | Content Page | Drag and Scroll | Up/Down Page | Combined Options |
| Mobile-Z | 25.0% | 4.2% | 37.5% | 33.3% |
| Mobile-M | 0.0% | 0.0% | 62.5% | 37.5% |
| Desktop-Z | 37.5% | 8.3% | 4.2% | 50.0% |
| Desktop-M | 29.2% | 8.3% | 37.5% | 25.0% |

The semistructured questionnaire is also used to collect the qualitative data. The students are asked to write down their opinions and suggestions regarding the operation devices and e-book systems, as given in Table 8. According to Table 8, there are some common problems with respect to the operation devices and e-book systems, such as *'the page number should be consistent with the 'Scroll' page'*. In addition, although the touchscreen mobile device is more intuitive for the students to read e-books, most students feel confused and make errors on *'how to turn to the next page'*, because some e-books are designed to the right-hand side, and others are to the left. This result could be provided as a guideline for e-book designers to design an effective user interface that can best meet students' requirements and satisfaction. For example, for the touchscreen mobile device, the students reveal that it is difficult to find the 'Content Page' on the Zinio e-book system, and suggest that the obvious design/icon should be given to improve the user interface. For a similar usability problem about the interface design, the MagV e-book system does not provide the 'Content Page' function. As such, the students cannot directly jump onto a specific page where they are interested, and can only scroll page-by-page thus increasing the operation time and the chance of making errors. This result is in line with the perspective of Kropman et al. (2004) that the user interface needs to be improved before being widely accepted as an alternative [32].

## 6. Conclusion and further research

In this paper, we have presented a user-centered experimental study on four test scenarios (i.e. Mobile-Z, Mobile-M, Desktop-Z, and Desktop-M) to address the problem of whether the touchscreen mobile device is user-friendly for students to read e-books with high reading performance and satisfaction. The analysis of variance (ANOVA) has been conducted to examine if different operation devices and e-book systems have a significant difference in terms of the operation time, error frequency, and subjective satisfaction. The experimental result has demonstrated that statistically significant interactions exist for specific reading tasks in terms of the operation time and error frequency. The result of ANOVA shows that the touchscreen mobile device requires less operation time and has few errors than the desktop computer, thus suggesting that the touchscreen is more effective and intuitive than the mouse and/or a keyboard for reading e-books. Students' reading performance can be significantly different when using different operation devices and/or e-book systems for performing specific reading tasks. Finally, the qualitative result obtained from the retrospective testing and the semistructured questionnaire provides e-book manufacturers and designers with a useful guideline for designing an effective user interface to enhance users' reading performance and satisfaction.

Although this study chooses the touchscreen mobile device, the desktop computer, the Zinio and MagV e-book systems as an illustration, the user-centered approach presented is applicable to other mobile devices (e.g. phablet or Flip PC) with various operating ways (e.g. force touch or 3D touch) and e-book systems (e.g. FlipViewer or FlipAlbum). In further experiments and studies, these devices or systems could be considered.

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The approach presented can be used as an effective mechanism for examining users' reading performance on various e-book devices and systems.

**Table 8.** Students' recommendations about the operation devices and e-book systems

| | The Zinio E-book System | The MagV E-book System |
|---|---|---|
| Mobile | Mobile-Z<br>• It is easy to read e-books with iPad, but is a lack of feeling about real turning pages.<br>• The page number should be consistent with the 'Scroll' page.<br>• It is difficult to find the 'Content Page', and should be improved with an obvious design/icon.<br>• How to turn to the next page is inconsistent and confusing (e.g. some to the right-hand side, and others to the left).<br>• The book should be marked if users have read it, and the label of books should be more visible and larger.<br>• The 'Scroll' function is unclear, and easy to make an error to turn to the next page. | Mobile-M<br>• The page number should be consistent with the 'Scroll' page.<br>• Users cannot jump onto a specific page, but scroll page-by-page.<br>• The time required for scrolling pages is longer than expected.<br>• For the convenience, books should be categorized into proper sections.<br>• The whole operation is not very smooth, and not easy to find the specific content.<br>• How to turn to the next page is inconsistent and confusing (e.g. some to the right-hand side, and others to the left).<br>• Resolution of display/interface is too low/fuzzy, particularly when the page is scaled up. |
| Desktop | Desktop-Z<br>• It is difficult to navigate smoothly when the page is scaled up.<br>• When the page is scaled up, the mouse could be used to better drag the page.<br>• The framework of the interface design is too complex and confusing.<br>• The page number should be consistent with the 'Scroll' page.<br>• The 'Scroll' function is unclear.<br>• Personalize the 'Choose Book' function, and add the personal favorite category.<br>• The indicator of the 'Drag Page' is occasionally slow and unclear. | Desktop-M<br>• The 'Content Page' should mark the page number of the article with a hyperlink.<br>• The whole operation is not intuitive and not very smooth.<br>• The interface design of the 'Choose Book' is too dazzling and unclear to follow.<br>• The 'Memory' function is good, but it would be better if users could adapt or modify it.<br>• The 'Keyword' function should be added to search the specific content.<br>• The 'Scale' function is unclear and cannot drag the page after being scaled up. |

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**References**

[1]. Apple (2015). https://www.apple.com/support/iphone/

[2]. Ardito, C., Lanzilotti, R., Costabile, M. F., & Desolda, G. (2013). Integrating traditional learning and games on large displays: An experimental study. Educational Technology & Society, 16, 44-56.

[3]. Baki, A. (2010). E-book usage of graduate students studying educational sciences in Turkiye. Turkish Online Journal of Distance Education, 11, 198-210.

[4]. BEA (2014). Measuring the e-book market. The 2013 Books and Consumers Annual Report. May 29, 2014.

http://www.publishersweekly.com/pw/by-topic/industry-news/bea/article/62579-bea-2014-measuring-the-e-book-market.html

[5]. Budiu, R. & Nielsen, J. (2011) Usability of iPad Apps and Websites. NIELSEN NORMAN GROUP.

[6]. Chang, K.-E., Wu, L.-J., Lai, S.-C., & Sung, Y.-T. (2014). Using mobile devices to enhance the interactive learning for spatial geometry. Interactive Learning Environments, DOI: 10.1080/10494820.2014.948458.

[7]. Chen, C.-H., Hwang, G.-J., Yang, T.-C., Chen, S.-H., & Huang, S.-Y. (2009). Analysis of a ubiquitous performance support system for teachers. Innovations in Education and Teaching International, 46, 421-433.

[8]. Chen, C.-M. & Lin, Y.-J. (2014). Effects of different text display types on reading comprehension, sustained attention and cognitive load in mobile reading contexts. Interactive Learning Environments, DOI:10.1080/10494820.2014.891526.

[9]. CNET (2013). Tablets buying guide. CNET's Buying Guide. November 22, 2013 by Xiomara Blanco and Eric Franklin.

http://www.cnet.com/topics/tablets/buying-guide/

[10]. Daniel, D. B., & Woody, W. D. (2013). E-textbooks at what cost? Performance and use of electronic v. print texts. Computers & Education, 62, 18-23.

[11]. De Jong, M. T., & Bus, A. G. (2004). The efficacy of electronic books in fostering kindergarten children's emergent story understanding. Reading Research Quarterly, 39, 378-393.

[12]. eMarketer (2014). Smartphone users worldwide will total 1.75 billion in 2014. January 16, 2014.

http://www.emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536

[13]. Felvegi, E., & Matthew, K. I. (2012). eBooks and literacy in K-12 schools. Computers in the Schools, 29, 40-52.

[14]. Freedman, D., Pisani, R., & Purves, R. (2007). Statistics (4th edition). W. W. Norton and Company.

[15]. Freedman, D. (2009). Statistical Models: Theory and Practice. Cambridge University Press.

[16]. Furió, D., González-Gancedo, S., Juan, M. C., Seguí, I., & Rando, N. (2013). Evaluation of learning outcomes using an educational iPhone game vs. traditional game. Computers & Education, 64, 1-23.

[17]. Grimshaw, S., Dungworth, N., McKnight, C., & Morris, A. (2007). Electronic books: Children's reading and comprehension. British Journal of Educational Technology, 38, 583-599.

[18]. Hung, C.-Y., Chang, T.-W., Yu, P.-T., & Cheng, P.-J. (2012). The problem-solving skills and learning performance in learning multi-touch interactive jigsaw game using digital scaffolds. Paper presented at the IEEE 4th international conference on digital game and intelligent toy enhanced learning, Takamatsu, Japan.

[19]. Hung, C.-Y., Sun, C.-Y., & Yu, P.-T. (2015). The benefits of a challenge: student motivation and flow experience in tablet-PC-game-based learning. Interactive Learning Environments, 23, 172-190.

[20]. Huang, Y. M., Liang, T. H., Su, Y. N., & Chen, N. S. (2012). Empowering personalized learning with an interactive e-book learning system for elementary school students. Education Technology Research Development, 60, 703-722.

[21]. Hwang, G.-J., Yang, T.-C., Tsai, C.-C., & Yang, S.-J. (2009). A context-aware ubiquitous learning environment for conducting complex science experiments. Computers & Education, 53, 402-413.

[22]. IDC report (2014). Worldwide tablet market grows 11% in second quarter on shipments from a wide range of vendors. 24 Jul 2014.

http://www.idc.com/getdoc.jsp?containerId=prUS25008314

[23]. IDC report (2014). Smartphone OS market share, Q3 2014.

http://www.idc.com/prodserv/smartphone-os-market-share.jsp

[24]. Ihmeideh, F. M. (2014). The effect of electronic books on enhancing emergent literacy skills of pre-school children. Computers & Education, 79, 40-48.

[25]. Jin, C.-H. (2014). Adoption of e-book among college students: The perspective of an integrated TAM. Computers in Human Behavior, 41, 471-477.

[26]. Kang, Y.-Y., Wang, M.-J. J., & Lin, R. (2009). Usability evaluation of e-books. Displays, 30, 49-52.

[27]. Kim, J., Lee, J., & Choi, D. (2003). Designing emotionally evocative homepages: An empirical study of the quantitative relations between design factors and emotional dimensions. International Journal of Human-Computer Studies, 59, 899-940.

[28]. Kim, J. U., Kim, W. J., & Park, S. C. (2010). Consumer perceptions on web advertisements and motivation factors to purchase in the online shopping. Computers in Human Behavior, 26, 1208-1222.

[29]. Knight, K., & Davies, R. S. (2014). Using a Mobile Dichotomous Key iPad application as a scaffolding tool in a museum setting. Interactive Learning Environments, DOI:10.1080/10494820.2014.924532.

[30]. Korat, O., & Shamir, A. (2008). The educational electronic book as a tool for supporting children's emergent literacy in low versus middle SES groups. Computers & Education, 50, 110-124.

[31]. KPCB (2014). KPCB Internet trends 2014. May 28, 2014.

http://www.slideshare.net/kleinerperkins/internet-trends-2014-05-28-14-pdf

[32]. Kropman, M., Schoch, H. P., & Yeoh, H. Y. (2004, December). An experience in e-learning: Using an electronic textbook. In R. Atkinson, C. McBeath, D. Jonas-Dwyer, & R. Phillips (Eds.), Proceedings of the 21st ASCILITE conference (pp. 512-515), Perth, Australia.

[33]. Lee, S. (2013). An integrated adoption model for e-books in a mobile environment: Evidence from South Korea. Telematics & Informatics, 30, 165-176.

[34]. Liaw, S.-S. & Huang, H.-M. (2014). Investigating learner attitudes toward e-books as learning tools: based on the activity theory approach. Interactive Learning Environments, DOI: 10.1080/10494820.2014.915416.

[35]. Liesaputra, V., & Witten, I. H. (2012). Realistic electronic books. International Journal of Human-Computer Studies, 70, 588-610.

[36]. Lin, Y.-C., Yeh, C.-H., & Wei, C.-C. (2013). How will the use of graphics affect visual aesthetics? A user-centered approach for web page design. International Journal of Human-Computer Studies, 71, 217-227.

[37]. Lin, Y.-C. (2015). User-centred evaluation to interface design of e-books. Lecture Notes in Computer Science, 8936, 220-226.

[38]. Lin, Y.-C., & Yeh, C.-H. (2015, July). Touch user interface evaluation for e-book systems: A usability experiment on Zinio and MagV. Proceeding of the Fifth International Conference on Ambient Computing, Applications, Services and Technologies (pp. 52-55), Nice, France.

[39]. MagV (2014). http://tw.magv.com/

[40]. Marketing Digest (2014). Global smartphone market grows 25.3% in Q2 2014. November 4, 2014 by Marketing Digest Writing Team.

http://marketingdigest.com/global-smartphone-market-grows-25-3-in-q2-2014/

[41]. Nielsen, J. (1993). Usability Engineering. Academic Press, United Kingdom.

[42]. Phadung, M., Suksakulchai, S., & Kaewprapan, W. (2012, October). The design framework of interactive storybook support early literacy learning for ethnic minority children. Paper presented at the World Congress on Engineering and Computer Science, San Francisco, USA.

[43]. Ploetzner, R., Fillisch, B., Gewald, P.-A., & Ruf, T. (2015). The role of student-generated externalizations in strategic multimedia learning and how current (web-) technology fails to support learner engagement. Interactive Learning Environments, DOI:10.1080/10494820.2015.1041401.

[44]. Ploetzner, R., Lowe, R., & Schlag, S. (2013). A systematic characterization of cognitive techniques for learning from textual and pictorial representations. Journal of Education and Learning, 2, 78-95.

[45]. Pruet, P., Ang, C. S., & Farzin, D. (2014). Understanding tablet computer usage among primary school students in underdeveloped areas: Students' technology experience, learning styles and attitudes. Computers in Human Behavior, In Press.

[46]. Pu, P., Chen, L., & Hu, R. (2012). Evaluating recommender systems from the user's perspective: Survey of the state of the art. User Modeling and User-Adapted Interaction, 22, 317-355.

[47]. Ruddle, R. A., Howes, A., Payne, S. J., & Jones, D. M. (2000). The effects of hyperlinks on navigation in virtual environments. International Journal of Human-Computer Studies, 53, 551-581.

[48]. Shamir, A., & Korat, O. (2006). How to select CD-ROM story books for young children: The teacher's role. The Reading Teacher, 59, 532-543.

[49]. Shin, D. H. (2011). Understanding e-book users: Uses and gratification expectancy model. New Media & Society, 13, 260-278.

[50]. Stevenson, C. (2004). E-books offer a new niche for writers. The Writer, 117, 31-33.

[51]. Sung, Y.-T., Hou, H.-T., Liu, C.-K., & Chang, K.-E. (2010). Mobile guide system using problem-solving strategy for museum learning: A sequential learning behavioral pattern analysis. Journal of Computer Assisted Learning, 26, 106-115.

[52]. Sung, Y.-T., Chang, K.-E., & Liu, T.-C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. Computers & Education, 94, 252-275.

[53]. Thielsch, M. T., Blotenberg, I. & Jaron, R. (2014). User evaluation of websites: From first impression to recommendation. Interacting with Computers, 26, 89-102.

[54]. Tractinsky, N., Katz, A. S., & Ikar, D. (2000). What is beautiful is usable. Interacting with Computers, 13, 127-145.

[55]. Vatavu, R.-D., Cramariuc, G., & Schipor, D. M. (2015). Touch interaction for children aged 3 to 6 years: Experimental findings and relationship to motor skills. International Journal of Human-Computer Studies, 74, 54-76.

[56]. Wang, P.-Y., & Yang, H.-C. (2014). The impact of e-book interactivity design on children's Chinese character acquisition. Interactive Learning Environments, DOI: 10.1080/10494820.2014.917112.

[57]. Willoughby, D., Evans, M. A., & Nowak, S. (2015). Do ABC eBooks boost engagement and learning in preschoolers? An experimental study comparing eBooks with paper ABC and storybook controls. Computers & Education, 82, 107-117.

[58]. Woody, W. D., Daniel, D. B., & Baker, C. A. (2010). E-books or textbooks: Students prefer textbooks. Computers & Education, 55, 945-948.

[59]. Wu, H. C., Lee, C. L., & Lin, C. T. (2007). Ergonomic evaluation of three popular Chinese e-book displays for prolonged reading. International Journal of Industrial Ergonomics, 37, 761-767.

[60]. Wu, T.-T. (2015). A learning log analysis of an English-reading e-book system combined with a guidance mechanism. Interactive Learning Environments, DOI: 10.1080/10494820.2015.1070272.

[61]. Yamamoto, M., & Lambert, D. R. (1994). The impact of product aesthetics on the evaluation of industrial products. Journal of Product Innovation Management, 11, 309-324.

[62]. ZINIO (2014). http://corp.zinio.com/

[63]. Zucker, T.A., Moody, A.K., & McKenna, M.C. (2009). The effects of electronic books on pre-kindergarten-to-grade 5 students' literacy and language outcomes: A research synthesis. Journal of Educational Computing Research, 40, 47-87.

[64]. Zywica, J., & Gomez, K. (2008). Annotating to support learning in the content areas: Teaching and learning science. Journal of Adolescent and Adult Literacy, 52, 155-165.

Touchscreen keyboard: a visual keyboard on the display screen of a mobile device that can be used in place of a physical keyboard. Universal Instructional Design (UID): A process that considers the potential needs of all learners when designing and delivering instruction; the process of identifying and eliminating unnecessary barriers to teaching and learning while maintaining academic rigor.Â Small screens make reading text difficult (Churchill & Hedberg, 2008), yet text remains the predominant content format within mobile learning (Shen, Gao, Novak, & Tang, 2009).Â  Considering usability in addition to performance can provide a more complete picture of the effect of device when answering multiple-choice and open-. 8. response questions.