

# The Effects of E-book Reading Purposes and Screen Formats on Reading Performance and Cognitive Loads of College Students

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## <Abstract>

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As e-books have become prevalent during the past few years, screen design of e-book readers (EBRs) has also become a key issue for better readability; EBR screen design should be such that it supports the reading process. The purpose of reading is important in determining a reader's strategy for text comprehension because readers adjust their thinking process to fit the purpose. This study therefore examines the effect of EBR screen formats designed to improve readability on reading performance and cognitive loads. The results revealed that reading for entertainment demanded the least mental effort. When participants were reading for study, their self-evaluation was higher than those of other groups. One interesting result was that the response time for secondary tasks was fastest when a reader's purpose was study using a multiple screen format EBR. Multiple screen format yielded better results by increasing mental effort and perceived ease of use. This result indicates that the multiple screen format is useful in managing the cognitive process of reading for study to organize information.

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## 1. Introduction

Using e-book at university has grown significantly over the past few years. E-book is gaining popularity for college students and faculty as well because it is easy to conduct academic searching and accessible from anywhere (Hernon, Hopper, Leach, Saunders & Zhang 2007). The advantages of reading from e-books are convenience and mobility. Although e-book requires a special device to display content, major publishers transform considerable portions of their publications into e-book (Quinn 2011). According to Miller (2011), 95% of academic libraries are providing access to e-book format. It indicates that use of e-book is becoming common (Bailey 2006, Rose & Li 2007, Walton 2007). Such a proliferation of producing e-book collections yields the dramatically increased use by students and faculty in higher education. Although the popularity of using e-book has been increasing, college students are not always preferred to e-book. Using e-book is not equivalent printed book in legibility and readability (Woody, Daniel & Baker 2010). Screen design for effective and/or efficient reading plays a critical role in ensuring better reading conditions.

### 1.1 Effective Screen Formats of E-book

Legibility indicates how quickly and accurately letters and words can be identified (Huang & Ma 2007). The more legible screen design is to make the better e-book for readers because they can easily recognize the letters, which are the basic elements of words and contents. Font style, point size, and typeface size are key features to enhance e-book look legible. High legibility facilitates readability of e-book when it has the greater perception of letters as well as the easier to read and understand. Addition to the importance of legibility, readability can be determined how the content is laid out on a screen. In an effort to design an effective screen layout, many navigational methods have been developed by placing text and graphics in various layout formats (de Bruijn & Spence 2000). Among them, multiple screen and sequential screen formats were mostly

employed methods to evaluate the effectiveness of screen layout (Barrett 2002, Lin & Ho 2007, Spence 2002).

Multiple screen format is to provide simultaneous information on the same screen. The simultaneous presentation on the same location provides readers with a series of images or information of learning contents to allow them to select their own learning sequence. Presenting information simultaneously on the dual-screen makes readers perceive learning effectiveness better and also reduce learners' cognitive load effectively than that on the single screen (Chang, Hsu & Yu 2011, Hsu, Chang & Yu, 2012, Kuo, Chang, Hsu & Yu 2009). In contrast, presenting successive information in a sequence is based on linearity. Linear presentation refers to display content pages successively like a slide show. The benefit of this method is to help readers focus on one page; thus, the reader can sequentially process his cognitive load on each page of e-book. However, sequential screen format may not be appropriate for those who want to compare other pages by cross-checking the content (Lin & Ho 2007, Spence 2002).

## **1.2 Reading Purposes and Cognitive Load**

Reading text consists of information retrieval and knowledge construction for readers to accomplish reading goals and organize new information into schema. While the reader is actively performing visual searching and organizing knowledge to transfer, the new information should be proceeded to build a meaningful schema (Bråten & Samuelstuen 2004, Linderholm 2006, Linderholm & van den Broek 2002). The best way to accomplish the reading goal with e-book is to help learners read the content more easily and organize the information efficiently. Reading requires various reading strategies to achieve the reading goal, and readers should match cognitive strategies and reading purpose (Bråten & Samuelstuen 2004, Linderholm & van den Broek 2002). Readers should match proper text-processing strategies with reading-text so that they increase cognitive coherence of reading (van den Broek, Lorch, Linderholm & Gustafson 2001).

Among the various reading purposes, readings for study and entertainment are the most distinctive reading purposes in regarding for very different cognitive strategies to read (Linderholm, Cong & Zhao 2008). Walton (in press) found that college students were more likely to engage in rereading text and to report knowledge-based coherence breaks when they read for examinations than for entertainment. In addition, van den Broek et al. (2001) found that college students read text with a study purpose to focus more on inferential structure of content than those who read with an entertainment purpose. Similarly, Linderholm and van den Broek (2002) reported that college students more often paraphrased and tried to connect text information for study whereas they produced more associations and elaborations of the reading text with personal experience when reading for entertainment.

### **1.3 Cognitive Loads in Reading**

It is important for a reader to manage his cognitive capacity in order to reach reading purposes so that he can efficiently manage his thinking process to understand without being overloaded. The invested amount of cognitive capacity indicates the imposed cognitive load to understand reading text. A cognitively designed screen layout can foster effective reading of text comprehension without imposing too much mental load on the reader's cognitive load (DeStefano & LeFevre 2007, Zumbach & Mohraz 2008). According to cognitive load theory (CLT), cognitive load is a mental allocation of performing a particular task (Sweller, van Merriënboer & Paas 1998), and an effective instruction has to be designed to reduce unnecessary cognitive load for learning (Paas, Renkl & Sweller 2004). By reducing the unnecessary cognitive load, learners can allocate more cognitive capacity to read and learn. CLT defines three types of cognitive load – intrinsic, extraneous, and germane. Intrinsic cognitive load is caused by the complexity of the content of the materials to be learned, and extraneous cognitive load by the format of the instructional materials provided; germane load is the mental effort invested directly in learning (Ayres & Paas 2009). The total cognitive load is the sum of the three types of cognitive load in a learner experience.

The cognitive load theory can be utilized to identify how well a screen format is appropriate for a specific reading purpose. If a reader has a study purpose to read, he needs to apply reading strategies of connecting information and elaborating relations within a reading material to organize the contents. With the study purpose, a multiple screen format would be a better way for him to support his cognitive process because the screen format is appropriate to present simultaneous information format on the same screen. A proper screen design will have a positive impact on increasing motivation to read. It may be necessary to increase learner's motivation, and encourage them to employ learning processes that yield germane cognitive load (van Merriënboer & Ayres 2005).

#### **1.4 Purpose of the Present Study**

The purpose of this study was to investigate a screen format of e-book with reading purposes on reading performance and cognitive load. Reading purposes are important for readers to select appropriate cognitive strategies. Reading purposes and screen formats were identified as key factors to affect readers' cognitive strategies and cognitive loads in reading e-book; however, the factors have not been investigated together. The screen formats may provide readers with external factors to read e-books whereas the reading purposes may guide internal cognitive process in understanding the text. In particular, screen formats and reading purposes are important for college students while the popularities of using e-book is increasing in these days in higher education. The purpose of this study was to identify the differences between screen formats and reading purposes that lead to different cognitive processes. For the purpose of study two representative reading purposes (study vs. entertainment) as well as two screen presentation formats (sequential screen vs. multiple screen) were compared regarding reading performance and cognitive load.

## **2. Methods**

### **2.1 Participants**

The participants of the study were undergraduate students registered in a public university located in one of six metropolitan cities in Korea. Ninety five students were recruited as a paid participation. The sample consisted of thirty five males (36.8%) and sixty females (63.2%). The ages of the participants ranged from 20 to 27 years old with a mean age of 22.30 (SD=2.11). The numbers of participants' grades were 23 freshman (24.2%), 32 sophomore (33.7%), 19 junior (20.0%), and 21 senior (22.1%).

### **2.2 Materials**

The participants read four topics of expository texts of human memory structures and functions. The sub-titles of text were “childhood amnesia (1,086 words)”, “flashbulb memory (1,147 words)”, “selective memory (1,113 words)” and “emotional memory (1,120 words)” written in Korean. The original text was written adult readers, and it was assumed that there was no problem to read the text for the study participants in terms of the vocabulary and expressions. In order to ensure the readability of text, a pilot study was conducted with twenty college students (9 males and 11 females). The difficulties of text were evaluated as normal to read and understand.

Desktop based e-book was developed for this study, and the participants can navigate and read expository text with mouse click. An oral presentation of how to use was given to the participants. Navigation methods were different from screen formats: 1) sequential screen format and 2) multiple screen format. First, sequential screen format presents one text page on the center of the screen (see Figure 1). The next button and back button were placed at the left and right side of the text page. The participants are able to linearly navigate throughout the four text pages.

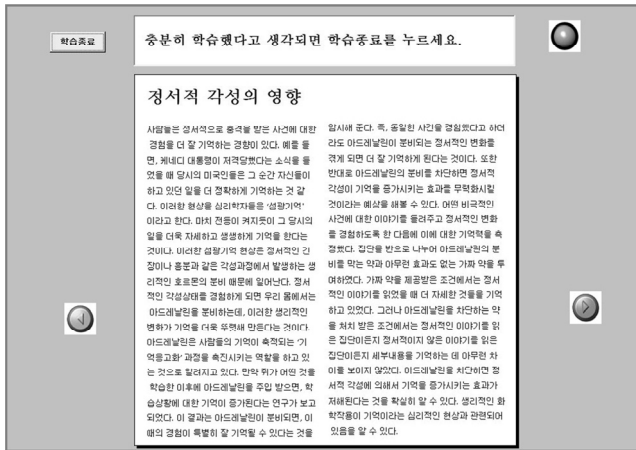


Figure 1 Screen Capture of Sequential Screen Format

In contrast, the multiple screen format simultaneously presents four pages on the screen. When a reader selects a page, it becomes centered on the screen with a large size while the other pages were presented as a small size around the centered page (see Figure 2). The participants were able to freely navigate the whole pages by clicking the small size pages.

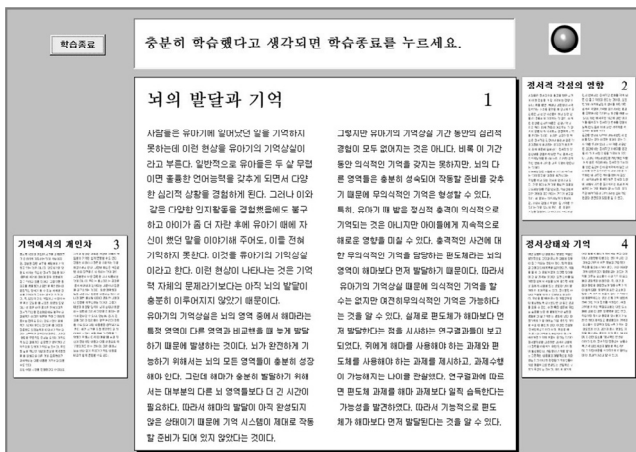


Figure 2 Screen Capture of Multiple Screen Format

## 2.3 Independent Variables

Screen formats and reading purposes were the independent variables of this study. First, the screen formats had two types: 1) sequential screen (see Figure 1 and 2) multiple screen formats (see Figure 2). Sequential screen format is to place the reading text in a sequential way so that a participant only can linearly navigate pages one by one. In contrast, multiple screen format is to simultaneously show several content screens on a monitor when a main screen is centered. Second independent variable was reading purposes: 1) reading for study, 2) reading for entertainment, and 3) reading without particular purpose. Reading purpose is very important for a reader to determine what cognitive strategies need to be activated. The three conditions were corresponding to 1) reading for study group (STU group), 2) reading for entertainment group (ENT group), and 3) no purpose as a control group (CON group) respectively.

## 2.4 Dependent Variables

### 2.4.1 Reading Performance

Completion time, comprehension test score, and response time were employed to measure performance of learning. The *completion time* is a total amount of time to read the given text, and it is assumed to measure how long readers pursue their task. The *comprehension test score* is to measure how accurately remember the facts in the text. The test was administered with eight multiple-choice question items, and the total score was eight. The *response time* (RT) of secondary task measures the behavioral reaction, the primary task. The faster reaction time of secondary task indicates that a learner has enough cognitive capacity remained. A button appeared on the screen as the secondary task during the reading task. The participants were instructed to click the button as soon as possible. The response time was defined as the time gap between appearance and click of the button.

### **2.4.2 Cognitive Load Factors**

The cognitive load factors (CLF) were to measure multi-dimensional aspects of cognitive loads of learning with multimedia (Ryu & Kim 2011). CLF consisted of five categories: 1) task demand, 2) mental effort, 3) perceived task difficulty, 4) self-evaluation, and 5) perceived easiness of use. Each category has four question items with 7 points Likert scale. Total question items are twenty. First, task demand (TDE) is a psycho-physical factor that measures how much a learner invests his effort physically to solve problems. The general description of task demand can be given as the amount of physical fatigue experienced in order to finish the relevant learning task. When mental demands for a task increase, learners supposedly perceive higher cognitive load. Second, mental effort (MEF) is the level of cognitive exertion experienced by the learner. This factor reflects an effort based on learners' allocation of cognitive resources for cognitive processing. The increased cognitive load may have a positive impact on schema acquisition. Third, perceived task difficulty (PTD) is an anticipated cognitive load caused by a given task. If a task has a high level of complexity, then learners' perception of its difficulty increases. Task difficulty is very sensitive to the level of the learner's prior knowledge and expertise on a given subject matter. Fourth, self-evaluation (SEV) is a personal perception of how successfully and/or efficiently a learner deals with a given problem to achieve desirable learning outcomes. The learner's subjective judgments are assumed to be an important factor for efficiency of learning. Last, perceived easiness of use (PEU) measures how well the learning content is used towards the learning purpose. If a learner's perception of usability is high, it indicates that the learning content can facilitate learning or at least will not impede the learning process. All of the question items were developed with 7 point Likert scale format. The overall internal consistency of CLF (TDE, MEF, PTD, SEV and PEU) was measured at .74.

### **2.5 Procedures and Data Analysis**

Before the experimental, the participants took a training session of what to do for the response time measure and navigation method. The reading

purposes were manipulated as a task for each group. For the reading for study group, they were asked to read the experimental text in preparation for a test after the experiment. For the group of reading for entertainment, they were asked to read the text trying to connect personal experience and the reading text. For the control group, no specific instruction was given to the participants. Rather, participants of the control group were asked to read the text as much as he would like to understand. After the participants completed the reading session, the paper-based cognitive load survey and comprehension test were administered. The entire procedure takes approximately 45 minutes.

A 3X2 factorial design was applied to this study. In order to identify the impact on the reading performance (completion time, comprehension score, and response time) a two way ANOVA was conducted for each sub-dependent variable. To examine the impact on cognitive load factors (CLF), 3x2 two way MANOVA was conducted.

### 3. Results

#### 3.1 Reading Performance

Table 1 shows the means and standard deviations of the completion time, comprehension scores, and response time. First, there was a significant main effect found in the completion time by reading purposes:  $F(2, 89)=3.70, p=.029$ . No significant difference was found by screen formats:  $F(1, 89)=.00, p=.978$ . Additionally, no significant interaction between reading purpose and screen design in the completion time was found:  $F(2, 89)=.06, p=.939$ . A Scheffe test of completion time between reading purposes was followed, but there was no significant difference among the reading purposes. Although there was a significant difference by reading purposes, it was not strong enough to show the group differences. It was not clear which reading purpose causes the main effect.

**Table1 Means and Standard Deviations of Completion Time, Comprehension Test, and Response Time (n=sample size)**

|                         |       | STD     | ENT      | CON     | Total   |
|-------------------------|-------|---------|----------|---------|---------|
| Completion Time         | SEQ   | 363.54  | 311.92   | 317.57  | 332.02  |
|                         |       | (98.98) | (80.78)  | (97.99) | (94.44) |
|                         |       | n=18    | n=16     | n=17    | n=51    |
|                         | MUL   | 367.11  | 316.35   | 308.08  | 330.64  |
|                         |       | (80.46) | (100.82) | (64.24) | (84.25) |
|                         |       | n=15    | n=13     | n=16    | n=44    |
| Comprehensi<br>on Score | Total | 365.16  | 313.90   | 312.97  | 331.38  |
|                         |       | (89.67) | (88.64)  | (82.21) | (89.40) |
|                         |       | n=33    | n=29     | n=33    | n=95    |
| Response Time           | SEQ   | 1132.94 | 1103.17  | 1107.34 | 1115.07 |
|                         |       | (47.91) | (52.15)  | (58.10) | (53.45) |
|                         | MUL   | 1079.25 | 1137.40  | 1127.80 | 1114.09 |
|                         |       | (71.25) | (124.09) | (49.56) | (86.40) |
|                         | Total | 1108.54 | 1118.51  | 1117.26 | 1114.61 |
|                         |       | (64.63) | (91.42)  | (54.29) | (70.25) |

NOTE: STD=Reading for study group  
 ENT=Reading for entertainment group  
 CON=No purpose (control group)  
 SEQ=Sequential Screen Format  
 MUL=Multiple Screen Format

Second, a  $3 \times 2$  factorial ANOVA was conducted, but there was no significant main effect in the comprehension test score by reading purposes ( $F(2, 89)=1.98, p=.144$ ) and screen formats ( $F(1, 89)=.12, p=.726$ ). No significant interaction in the comprehension test score between reading purposes and screen formats was found:  $F(2, 89)=.35, p=.707$ .

Third, there was no significant main effect by reading purposes:  $F(2, 89)=.37, p=.689$ . Neither was a significant main effect by screen formats:  $F(1, 89)=.00, p=.981$ . However, there was a significant interaction between reading purposes and screen formats with  $F(2, 89)=3.69, p=.029$ . A simple main effect analysis was followed and revealed that there was a

significant difference between screen formats at reading for study ( $F(1, 89)=4.74, p=.032$ ). Multiple screen format showed much quicker response time to sequential screen format when the reading purpose was for study (see Figure 3).

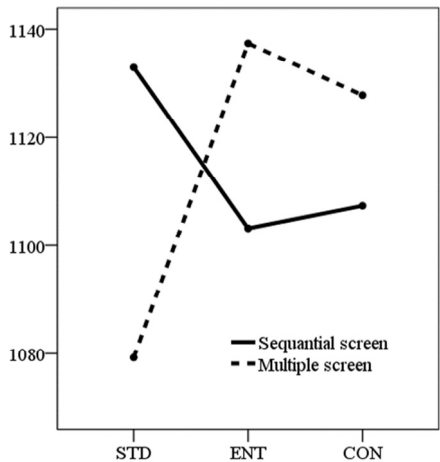


Figure3 Mean of the Response Time by Reading Purposes and Screen Formats

### 3.2 Cognitive Load

Table 2 shows the means and standard deviations of cognitive load factors (TDE, MEF, PTD, SEV, and PEU). Box’s M Test of equality was satisfied (Box’s  $M=94.35, F=1.07, p=.314$ ). The reading purposes have no significant effect on the dependent variables: Wilks’ Lambda values of the reading purposes ( $F(10, 172)=2.23, p=.018$ ). However, there were no significant effect of screen formats ( $F(5, 172)=2.01, p=.085$ ) and no significant interaction effect as well ( $F(10,170=.90, p=.537$ ).

**Table2 Means and Standard Deviations of the Cognitive Load Factors**

|                                       |       | STD         | ENT         | CON         | Total       |
|---------------------------------------|-------|-------------|-------------|-------------|-------------|
| Task Demand<br>(TDE)                  | SEQ   | 3.56 (.74)  | 3.23 (1.39) | 3.24 (1.43) | 3.35 (1.20) |
|                                       | MUL   | 2.75 (1.35) | 3.02 (1.44) | 3.33 (1.34) | 3.04 (1.36) |
|                                       | Total | 3.19 (1.12) | 3.14 (1.39) | 3.28 (1.37) | 3.21 (1.28) |
| Mental Effort<br>(MEF)                | SEQ   | 5.57 (.80)  | 4.94 (.70)  | 5.57 (.86)  | 5.37 (.83)  |
|                                       | MUL   | 5.67 (.64)  | 5.53 (1.20) | 6.14 (.75)  | 5.80 (.90)  |
|                                       | Total | 5.61 (.72)  | 5.20 (.98)  | 5.85 (.85)  | 5.57 (.88)  |
| Perceived Task<br>Difficulty<br>(PTD) | SEQ   | 3.33 (1.20) | 3.57 (1.01) | 3.01 (.91)  | 3.30 (1.06) |
|                                       | MUL   | 3.20 (1.15) | 3.15 (1.20) | 3.11 (1.20) | 3.15 (1.15) |
|                                       | Total | 3.27 (1.16) | 3.39 (1.10) | 3.06 (1.04) | 3.23 (1.10) |
| Self-evaluation<br>(SEV)              | SEQ   | 4.91 (.82)  | 4.14 (.74)  | 4.61 (.72)  | 4.57 (.81)  |
|                                       | MUL   | 4.87 (.73)  | 4.38 (.87)  | 5.21 (.75)  | 4.85 (.83)  |
|                                       | Total | 4.89 (.77)  | 4.25 (.80)  | 4.90 (.78)  | 4.70 (.83)  |
| Perceived<br>Easiness of Use<br>(PEU) | SEQ   | 4.51 (1.20) | 4.17 (.73)  | 3.94 (.81)  | 4.22 (.96)  |
|                                       | MUL   | 5.03 (1.31) | 4.35 (1.17) | 4.67 (1.09) | 4.70 (1.20) |
|                                       | Total | 4.75 (1.26) | 4.25 (.94)  | 4.30 (1.01) | 4.44 (1.10) |

NOTE: STD=Reading for study group

ENT=Reading for entertainment group

CON=No purpose (control group)

SEQ=Sequential Screen Format

MUL=Multiple Screen Format

Further analysis of between subject effect was conducted, and two significant main effects were found by the reading purposes on MEF ( $F(2, 89)=4.34, p=.016$ ) and SEV ( $F(2, 89)=6.81, p=.002$ ). A post-hoc test was conducted for MEF and SEV. Regarding the effect on MEF, ENT group showed lower level of there was a significant difference ( $p=.008$ ) on MEF between ENT and CON. It indicated that entertainment group showed lower mental effort than the control group did. Regarding the effect on SEV, a post-hoc test revealed that ENT was lower than both STD and CON. The entertainment group showed the lowest level of self-evaluation. There were two significant difference on MEF ( $F(1, 92)=6.00, p=.016$ ) and PEU ( $F(1, 92)=5.30, p=.034$ ) by the screen formats. Regarding the screen formats, the multiple screen format was better than the

sequential screen format for mental effort (MEF) and perceived ease of use (PEU).

## **4. Discussions**

### **4.1 Reading Performance**

In this study, completion time, comprehension test score, and response time were measured to examine the effect on reading performances. First, there was a significant main effect of reading purpose on completion time. According to a previous study, college students who read for study reported that their reading time for texts was relatively longer (Linderholm et al., 2008). However, a post-hoc test did not reveal any significant differences between the reading purposes.

Second, there was no significant difference in the comprehension test score among the reading purposes. Previous studies have also reported no significant difference of learner comprehension by reading purposes (Linderholm et al. 2008, Linderholm & Wilde 2010). Regarding the impact by screen formats, no significant differences were found in neither completion time nor comprehension test score. This result indicates that screen formats do not have any impacts on behavioral aspects of reading performance.

Third, there was a significant interaction effect of response time between the reading purposes and screen formats. Multiple screen format with the readers for study performed the fastest response time, whereas sequential screen format with the study purpose did the slowest one. This result indicates that multiple screen format is more suitable for study and can reduce reader's extraneous cognitive load.

### **4.2 Cognitive Load Factors**

The cognitive load factors (CLF) were investigated how the reading purposes and screen formats had impacts on. Reading purposes had impacts on mental effort and self-evaluation. A post-hoc test revealed that the participants with the entertainment purpose showed significantly lower mental effort than those with the no reading purpose. The group

with entertainment purpose typically uses individual experience-based cognitive strategies and spends a shorter amount of time reading the text. It shows that readers with entertainment purpose mentally concentrate less on the text than those under other conditions. The results of self-evaluation showed that readers for study perceived higher self-evaluation than others. According to a post-hoc test, there was a significant difference between study and entertainment purposes. When the learners read for study, they perceived that they had a better understanding of the task and felt that they had succeeded in it. It seems that they were encouraged to use specific cognitive strategies when they read for study. While they were trying to memorize or reread the text, they perceived that they understood the contents. As a result, their self-evaluations were higher.

Screen formats have significant impacts on mental effort and perceived ease of use as well. It was found that the multiple screen formats can increase the readers' mental effort and perceived ease of use. Readers perceived the multiple screen format as more effective formats than the sequential screen format regardless of the reading purposes. Because the multiple screen format presents all of the pages of reading text on a single screen, readers could see overall pages and rapidly complete visual searching to each page they wanted to see. It was predicted that the sequential screen format is more effective to manage cognitive load because it does not provide too much information. However, unlike to the prediction, the results showed that multiple screen format is successfully reducing readers' cognitive load with reading for study. When reading for study, readers need to memorize, organize, and reread the text for preparing a test, so that multiple screen format was an effective format that enabled readers to rapidly reread and access the texts. Multiple screen format, which allows readers to see several pages simultaneously, could reduce cognitive load. It was concluded that readers with multiple screen format shows faster response time when reading for study.

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# 電子書籍の読書目的と画面フォーマットが 読者に与える影響

－大学生の読書行為とその認知的負荷に注目して－

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## ＜要 旨＞

近年、電子書籍の普及が進むにつれて、電子書籍の読みやすさを高めるための画面設計が重要な課題となっている。電子書籍の画面設計を行う目的は読書のプロセスを支援することにある。読者は読書目的に沿って自分の思考プロセスをはたらかせようとするので、読書目的は読書方略を大きく左右するといえる。本稿の目的は、電子書籍の読みやすさを高める上で、画面フォーマットが読者にどのような影響を与えるかを、読書行為とその認知的負荷の観点から検証することである。その結果、娯楽目的の読書に要する心理的努力は最も少ないことがわかった。学習目的の読書の場合、彼らの自己評価は他目的の読書の場合よりも高かった。学習者が電子書籍で複数の画面フォーマットを扱う場合、副次的作業への反応は最も速かった。複数の画面フォーマットを用いると、心理的努力は増大し、使いやすさも向上することがわかった。このことから、情報を組織化する学習活動として読書行為を行う場合、複数の画面フォーマットを用いることは認知プロセスにおいて有効であるとの示唆が得られた。

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