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Visual design guidelines for improving learning from dynamic and interactive digital text

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ABSTRACT

Despite the dynamic and interactive features of digital text, the visual design guidelines for digital text are similar to those for printed text. The purpose of this study was to develop visual design guidelines for improving learning from dynamic and interactive digital text and to validate them by controlled testing. Two structure design guidelines (for enhancing text structure comprehension) and two selective-attention design guidelines (for maintaining the learners' attention on the essential contents) were developed based on the psychological and instructional, technological foundations that can affect the visual design of digital text. In this study, a 2×2 factorial design with 141 university students was used to examine the effectiveness of the visual design guidelines. The university students had 20 min to study a piece of digital text with the structure design guidelines, selective-attention design guidelines, both, or no design guidelines applied. Both the structure and selective-attention design guidelines had a positive influence on text structure understanding, essential contents comprehension and usability of digital text. The suggested visual design guidelines were found to be useful for enhancing text comprehension.

1. Introduction

As learning from in web-based environments is being used increasingly, it has become more important to determine how to visually design digital text to support student learning. Digital text can contain a range of multimedia, such as text, graphics, movie clips and audio components. The present study covers only text.

Digital text has interactive and dynamic advantages in utilizing web technologies, and there is a similarity of the basic cognitive process associated with reading digital and traditional text (Shapiro & Niederhauser, 2004). Nevertheless, students sometimes have difficulties in learning from digital text, such as i) difficulties in understanding the text structure or recognizing where readers are in the digital text (Dillon & Jobst, 2005; Sung & Mayer, 2012), and ii) difficulties in focusing on important materials (Loman & Mayer, 1983).

A range of visual design principles and guidelines have been suggested to help the student comprehend the structure and recognize the important information in digital text (Aspillaga, 1996; Chen & Rada, 1996; Galitz, 2007; Grabinger, 1989; Hartly, 1985; Jonassen & Wang, 1993; Lohr, 2003; Lorch, 1989). Most of these visual design principles and guidelines of digital text are grounded in them of printed text (Rieber & Welliver, 1989; Shapiro & Niederhauser, 2004) because of the comparable basic reading processes (Wenger & Payne, 1996). Therefore, most text design guidelines for digital text are guided by the design of the static textual component, even though web technology has the capability of dynamicity and interactivity (Park & Hannafin, 1993). In other words, there has been insufficient research on the visual design guidelines of dynamic and interactive digital text and little empirical work has been reported in this area.

The aim of this study was to develop and validate visual design guidelines for dynamic and interactive digital text to enhance students' comprehension of the structure and recognition of the essential contents. Furthermore, experiments were conducted to determine if the students comprehended the structure and important materials with digital text better when they learned from the digital text designed according to the dynamic and interactive visual design guidelines.

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2. Theoretical foundations for visual design

The psychological, instructional and technological foundations represent the fundamental influences affecting the visual design of digital text. These three foundations should be reflected when designing digital text visually in an effective manner.

Related to psychological foundations, which provide empirical implications for the visual design of digital text, visual perceptual principles grounded in gestalt theory have suggested effective ways of designing digital text (Chang, Wilson, & Dooley, 2003–2004; Moore & Fitz, 1993; Smith-Gratto & Fisher, 1998–99). Visual perceptual principles explain how individual elements are organized into groups or structures, and how visual stimuli are interpreted in meaningful and consistent ways. Perceptual organization and focal point are representative among various visual perceptual principles (Aspillage, 1996; Chang, Dooley, & Tuovinen, 2002; Chang & Nesbitt, 2005; Palmer, Brooks, & Nelson, 2003; Smith-Gratto & Fisher, 1998–99). Perceptual organization means that visual elements tend to be grouped according to the similarity, contiguity, proximity and common fate of the visual elements' attributes (Goldstein, 2007). This principle can be used to help learners comprehend the text structure. The principle of focal point refers to elements in a visual display that catch a person's attention (Lauer, 1979) and this principle can be applied to the core content that the learner should concentrate on. People naturally perceive the elements as focal points if the attributes of those elements are significantly different from the others (Chang & Nesbitt, 2005). The design implications to visuals that visual perceptual principles suggest are as follows: i) to present text in a semantic portion, and ii) to design core text showing different attributes from the rest.

The instructional foundations for designing ways of assisting a learner's text comprehension can be found in research on text segmentation, spacing, typographic cueing, organizational signals, semantic displays, etc. Text segmentation and spacing that relate to perceptual organization principles previously suggested, present ways of organizing and presenting text in internally consistent idea units (Hartly, 1985; Mayer, 1984; Park & Hannafin, 1993). Hartly (2004) suggested that paragraphs be separated by one line space and subheadings be separated from paragraphs by two extra lines above and one below them. Typographic cueing (such as bold, underline or color) that relate to the focal point principle is effective in improving all the cued information (Beck, 1991; Dyson & Gregory, 2002; Park & Hannafin, 1993).

Organizational signals can be defined as any writing device that emphasizes the topics of a particular text and their organization without altering the meaning or content of the text (Kardash & Noel, 2000). Many studies have also examined whether organizational signals, such as headings, overviews and topical summaries, increased the representation of the text structure (Lorch, 1993; Lorch & Lorch, 1996) and attention (Hyona & Lorch, 2004). Although the effect of semantic displays (e.g. graphical browsers, conceptual maps, and graphic organizers) on the cognitive structure is uncertain (Shapiro & Niederhauser, 2004), recent studies have shown that a visual representation of the hierarchical structure can affect the construction of text structure (Sung & Mayer, 2012). The design implications to visuals that instructional foundations suggest are i) to design text in a unit depending on the semantic groups by means of "white space" based on the law of proximity, ii) to present the core message of text in bold, underlined or highlighted with a brighter color, iii) to present the overviews or topical summaries, and iv) to visualize the organization of the text hierarchy.

Digital technological innovation has gradually improved the potential for the visual design of digital text (Hostetler, 2000). The technological characteristics of digital text that can affect the text designs include interactivity, dynamicity and visualization. Interactive technology provides a user-directed environment, which presents the individually requested visual forms of digital text according to the reader's choice (Park & Hannafin, 1993). In particular, a range of control options can be offered to readers in digital text. Text can be presented with dynamic forms that change the color, size, or position over time (Ford, Forlizzi, & Ishizaki, 1997). Kinetic typography, which is a combination of typography and motion, can be effective in conveying the affective quality of text and guiding the reader's attention (Lee, Forlizzi, & Hudson, 2002). Another challenge of digital text design is text visualization, which spatially transforms text information into a new visual representation to enhance visual browsing and analysis (Wise et al., 1995). Many applications of related text visualization are available. These include the thumbnail matrix approach (see Adobe Acrobat and Microsoft PowerPoint) and Flip Zooming using a fish-eye view technique (Holmquist, 1998) for presenting an overview of digital text as well as the Document Lens (Robertson & Mackinlay, 1993) and Hyperbolic Browser (Lamping & Rao, 1996) represent the hierarchical structure of digital text. The kinetic typographic approach can be used to guide the learner's attention and the text visualization approach provides design implications for representing the text structure.

Regarding visual design of the text concerned, many critical design principles based on psychological and instructional foundations have been suggested such as Williams (1994) and Lohr (2003). According to existing research, visual design principles provide useful guidelines for static digital text but have limitations in interactive and dynamic digital text. To this point, the present study aims to develop visual design guidelines to improve learning by interactive and dynamic digital text as well as to validate its effectiveness.

3. Visual design guidelines of dynamic and interactive digital text

The visual design guidelines of dynamic and interactive digital text are discussed in this section (See Table 1). The guidelines are not all inclusive, but represent the range of empirically-referenced visual design guidelines that can be extracted from theoretical foundations. Those same guidelines with the printed text out the total were excluded. A total of four guidelines are suggested; two for enhancing comprehension of the text structure and two for helping learners focus on the important content.

3.1. Guideline 1.1 visualize the relationships between paragraphs and pages

To visualize the relationship between pages, present the related paragraphs in a single page and arrange the related pages closer to each other or use the same background color so that they can be detected as the same group. The relationships among paragraphs and pages should first be understood to grasp the structure of digital text (Meyer & Rice, 1984). Accordingly, presenting a page with its related paragraph as a semantic group can help learners comprehend the relationship better. Whereas printed text is restricted to a certain size prevents it from being linked to related paragraphs as the same page, digital text enables such space or size utilized. With expository text for

Table 1
Visual design guidelines of dynamic and interactive digital text.

Visual design guidelines	Related research
To help comprehend text structure	
1.1. Visualize the relationships between the paragraphs and pages: • Present the related paragraphs in a single page • Locate the pages that are interconnected in meaning closer to each other or present them in an identical background color so that they can be detected as a same group visually	• Use space to separate the paragraphs, subsections, and chapters from one another (Hartley, 1985) • Place closely related elements together (Lohr, 2003) • Use color to help users understand what does and does not go together (Leavitt & Shneiderman, 2006) • Use longer, scrolling pages when users are reading for comprehension (Leavitt & Shneiderman, 2006) • Visualize the relationships between the pages (Jonassen & Wang, 1993; Sung, 2009)
1.2 Visualize hierarchical structure between pages and present the selected page in the overall hierarchical structure context: • Present the hierarchical structure of the total pages using the hyperbolic tree technique and enlarge the selected page in the overall hierarchical structure context	• Use a multi-window browser to organize pages hierarchically (Kandogan & Shneiderman, 1997) • Visualize information with a focus-context technique that allow the viewer to inspect the specific part in detail without losing global context (Lamping & Rao, 1996) • Use tree diagram, treemap, & corn tree to visualize the hierarchical information structure (Jerding & Stasko, 1998)
To help focus on important contents	
2.1 Visualize the meaning of the keywords or key phrases with motion: • Present the title or key phrases dynamically in an image so that their meanings can be visually prominent	• Convey tone of voice, emotion, and personality through moving characters (Ford et al., 1997) • Direct or manipulate explicitly the attention of the viewer through a time-based presentation of the text (Lee et al., 2002)
2.2 Present keywords or key phrases in order: • Present keywords or key phrases by each page in consecutive order using a time-based presentation technique	• Summarize the learning materials or lectures to enhance comprehension and recall of content (King, 1992; Wittrock & Alesandrini, 1990) • Design summary pages at the end of e-learning lessons (Alessi & Trollip, 2001)

learning, when divided by a title, the page is likely to contain a scroll device. Leavitt and Shneiderman (2006) suggest that the scroll technique is more effective than paging technique if the purpose is reading and understanding the digital text deeply.

3.2. Guideline 1.2 visualize hierarchical structure between pages and present the selected page in the overall hierarchical structure context

The relationship between each page is visualized in the hierarchical structure, and the selected page is enlarged and presented in the overall hierarchical structure context by applying to a hyperbolic tree technique. All text can be configured in a hierarchical structure and presenting the hierarchical structure of the text visually helps the learner better understand the text structure. As stated earlier, several studies have examined the visualization of text structure, such as graphic browser (Jonassen & Wang, 1993) and graphic organizer (Kenny, 1992). All these examples highlight the difficulty in locating the structural position on the selected page due to the disappearance of the overall structure when one page is selected. To solve the problems, a hyperbolic tree technique is used in a hierarchical structure of information, and presents enlarged information selected with the overall structure. When applied to digital text, the hyperbolic tree technique provides the overall structure with the location information of the pages selected.

3.3. Guideline 2.1 visualize the meaning of the keywords or key phrases with motion

To induce perceptual arousal, transform the semantic meaning of the keywords into an image with motion. The ways to visualize key phrases include those using a kinetic typographic technique, such as text size adjusting, text rotating, dynamic rhythm and show time adjusting. Text enables the addition of spatial depth by adjusting its size, and conveys dynamic energy and emotional feelings by rotating themselves. Moreover, text is capable of delivering dynamic images or movements, such as trembling by a gust of wind and swelling like a balloon. Presenting text by featuring the meaning of key phrases enhances the ability of the learner to memorize the text by delivering a clearer meaning as well as paying selective attention to the key parts.

3.4. Guideline 2.2 present keywords or key phrases in order

The keywords or key phrases by page are presented in consecutive order using a time-based presentation technique. This is done to help the learners preview the key contents before reading the entire digital text or overview the key contents after reading the text. The text preview activity presents and dynamizes the learners with prior information, and encourages their interest in the text (Jensen, 1986; Nist & Holschuh, 2000), whereas providing an opportunity for an overview after reading affects the understanding of the text contents and recall (Kintsch & van Dijk, 1978). Traditional printed text or e-learning lesson materials contain an overall summary at the end of the page, but the summary is likely to fail to meet the effectiveness so long as the learner has solid comprehension of it because one of potential reasons is that a summary does not include location information. To address this, the key phrases are set to stand out by making the rest of text transparent, and are displayed in a time-based presentation format.

4. Research method for visual design guidelines validation

The visual design guidelines of digital text were validated by controlled testing based on the developmental research methodology, as suggested by Tracey and Richey (2007). An experimental study was carried out examine the effect of digital text developed according to the visual design guidelines on the learner's comprehension. The specific research questions were as follows:

1) To what extent do visual design guidelines influence the learner's comprehension of the text structure?
2) To what extent do visual design guidelines help the learner focus on the important information and recall the important content?
3) To what extent do visual design guidelines influence the learners' usability ratings?

4.1. Participants and design

The participants were 146 fourth-year undergraduate students (35 males, 111 females) enrolled in an introductory educational technology course at a university in South Korea. Among the 146 students, five students did not answer all the test questions and were excluded. Therefore, the final number of participants were 141 fourth-year undergraduate students (34 males, 107 females) with a mean age of 24.05 years (SD = 1.89). All participants had experience in learning from digital text.

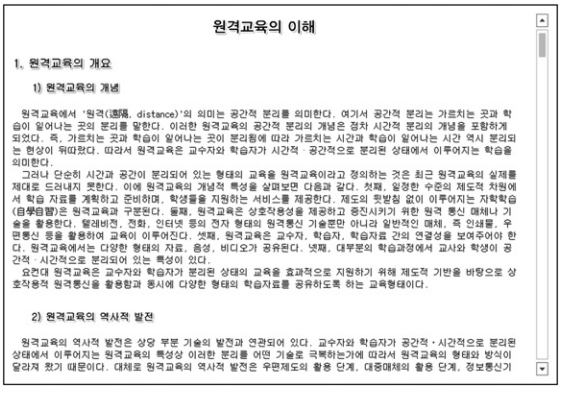
The participants were assigned randomly to one of four groups based on a 2 × 2 design. The first factor was whether to apply the visual design guidelines to enhance the text structure comprehension (structure design guidelines), and the second factor was whether to apply the visual design guidelines to help the reader focus on the important materials in digital text (selective-attention design). Thirty six students (9 males, 27 females) were included in the structure and selective-attention design group, which received the digital text designed with both types of design guidelines. Thirty five students (8 males, 27 females) were in the structure design group, 35 students (9 males, 26 females) were in the selective-attention design group, and 35 students (8 males, 27 females) were in the control group, which received the digital text designed with neither type of design guideline.

4.2. Materials and apparatus

The web-based learning materials consisted of four types of digital text on "Understanding of Distance Education." The digital text had three main sections with nine subsections: (1) introduction of distance education, which included two subsections on the definition and history of distance learning; (2) theories of distance learning, which included four subsections on independence and autonomy, industrialization of teaching, interaction and communication, and extension of learning space; and (3) practical issues in distance learning, which included three subsections on instructional environment, role of the instructor, and management strategies. All participants were native Korean speakers, all text was in Korean.

Fig. 1 shows a screenshot from the standard type of digital text for the control group, in which neither structure design guidelines nor selective-attention design guidelines were applied. The controlled condition was intended to approximate a standard type of digital text in a web-based environment. A title was presented at the top center of the text, and each heading and subheading was enlarged and in bold to be prominent compared to the body text. In addition, a single blank line was inserted between the subheadings to provide a cue for content transition. The page was configured using a scrolling technique instead of a paging technique because the type of text was the expository type.

Fig. 2 shows screenshots from the selective-attention design type of the digital text for the selective-attention design group, in which two visual design guidelines were applied to help the student focus on the important material in the given digital text. First, the key phrases were highlighted, and when clicked, the meaning was expressed in visual format using the kinetic typographic technique. For example, when d was clicked in the upper screenshot of Fig. 2, as indicated at the bottom left of the screenshot, the meaning was presented in visual format to emphasize the contents. Second, the core phrases were designed to be presented in consecutive order according to the flow of content. When "a" from the top left menu in Fig. 2 was clicked, as presented in the bottom right screenshot, the core phrases in accordance with the headings were displaced automatically and the learners were able to maneuver to their choice freely using the bottom control bar.


원격교육의 이해

1. 원격교육의 개요

1) 원격교육의 개념

원격교육에서 '원격(遠隔, distance)'의 의미는 공간적 분리를 의미한다. 여기서 공간적 분리는 가르치는 곳과 학습이 일어나는 곳의 분리를 말한다. 이러한 원격교육의 공간적 분리의 개념은 점차 시간적 분리의 개념을 포함하게 되었다. 즉, 가르치는 곳과 학습이 일어나는 곳이 분리됨에 따라 가르치는 시간과 학습이 일어나는 시간 역시 분리되는 현상이 뒤따랐다. 따라서 원격교육은 교수자와 학습자가 시간적 · 공간적으로 분리된 상태에서 이루어지는 학습을 의미한다.

그러나 단순히 시간과 공간이 분리되어 있는 형태의 교육을 원격교육이라고 정의하는 것은 최근 원격교육의 실제를 제대로 드러내지 못한다. 이에 원격교육의 개념적 특성을 살펴보면 다음과 같다. 첫째, 일정한 수준의 제도적 차원에서 학습 자료를 계획하고 준비하며, 학생들을 지원하는 서비스를 제공한다. 제도의 뒷받침 없이 이루어지는 자학학습(自學自習)은 원격교육과 구분된다. 둘째, 원격교육은 상호작용성을 제공하고 증진시키기 위한 원격 통신 매체나 기술을 활용한다. 우편서신, 전화, 인터넷 등의 전자 형태의 원격통신 기술뿐만 아니라 일반적인 매체, 즉 인쇄물, 우편통신 등을 활용하여 교육이 이루어진다. 셋째, 원격교육은 교수자, 학습자, 학습자들 간의 연결성을 보여주어야 한다. 원격교육에서는 다양한 형태의 자료, 음성, 비디오가 공유된다. 넷째, 대부분의 학습과정에서 교사와 학생이 공간적 · 시간적으로 분리되어 있는 특성이 있다.

요컨대 원격교육은 교수자와 학습자가 분리된 상태의 교육을 효과적으로 지원하기 위해 제도적 기반을 바탕으로 상호작용적 원격통신을 활용함과 동시에 다양한 형태의 학습자료를 공유하도록 하는 교육형태이다.

2) 원격교육의 역사적 발전

원격교육의 역사적 발전은 상당 부분 기술의 발전과 연관되어 있다. 교수자와 학습자가 공간적 · 시간적으로 분리된 상태에서 이루어지는 원격교육의 특성상 이러한 분리를 어떤 기술로 극복하는가에 따라서 원격교육의 형태와 방식이 달라져 왔기 때문이다. 대체로 원격교육의 역사적 발전은 우편제도의 활용 단계, 대중매체의 활용 단계, 정보통신기

Fig. 1. A screenshot of the digital text for the control group.

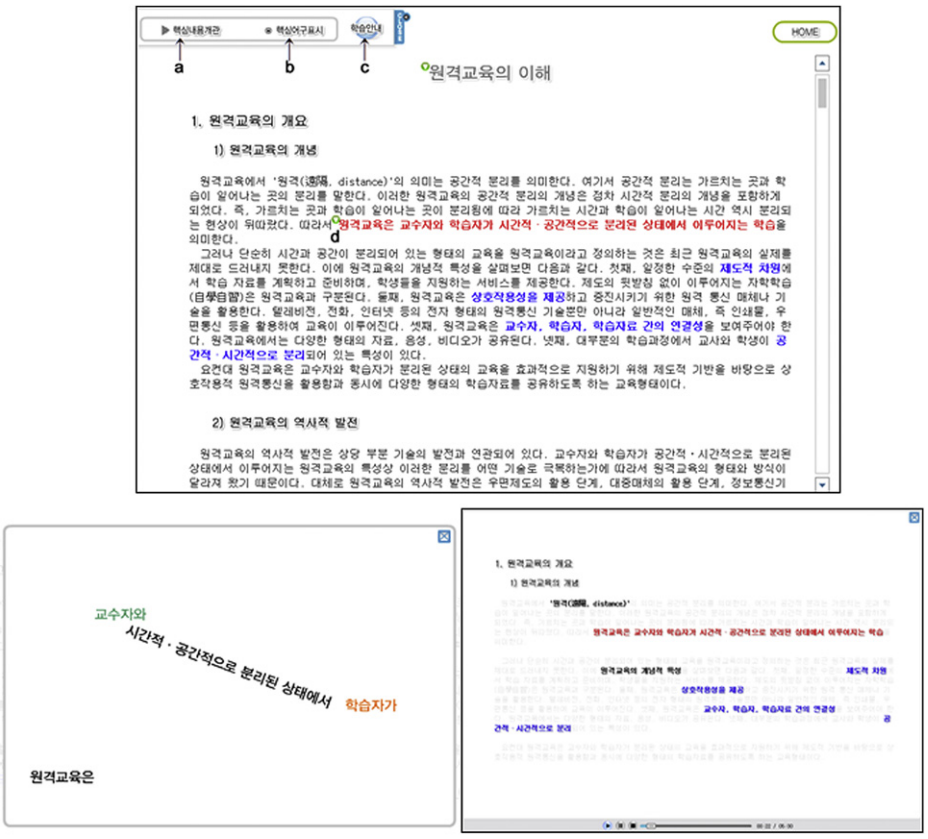


Fig. 2. Screenshots from the selective-attention design type of digital text. a: Menu for presenting key phrases in order. b: Menu for activating buttons to visualize key phrases (default selected). c: Menu for guiding the way to use this digital text. Note: Actual screens were rendered in color. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 3 shows screenshots from the structure design type of the digital text for the structure design group, in which the two visual design guidelines were applied to help the student comprehend the structure of the digital text presented. First, the relationships between the paragraphs and pages were visualized. To visualize the relationship between paragraphs, each page was configured by each heading and the pages interconnected by meaning were placed closer to each other compared with the other pages. Therefore as shown in Fig. 3, the subpages included in the three main sections were presented closer to each other. Second, the relationship between each page was visualized in the hierarchical structure and the selected page was presented in the overall hierarchical structure context, as shown in the bottom screenshot of Fig. 3.

Fig. 4 shows screenshots from the structure and selective-attention design type of the digital text, in which four visual design guidelines were applied to enhance digital text comprehension. In particular, this type is the combined package of the structure design type and the selective-attention design type.

Two rounds of expert reviews and learner usability tests were carried out to determine if the suggested visual design guidelines were implemented appropriately in the developed digital text. A total of three modification and supplementation runs were performed. The group of experts had at least three years instructional design experience and currently works as instructional designers. Five learners were from the same schools as the experiment group learners, who did not participate in this research.

For the final four types of digital text, an expert validation test was conducted on how appropriately the visual design guidelines were implemented. A total of eight experts were chosen according to their background and expertise in visual design of digital text or e-learning. Four of the experts held a doctoral degree in educational technology and the other four were instructional designers with at least three-year experience. Using a five-point likert-type scale (strongly disagree/strongly agree), the eight experts were asked about the implementation suitability on each visual guideline. As a result, all experts who participated in the validation test responded with at least four points (G 1.1: $M = 4.75$, SD = .33; G 1.2: $M = 4.88$, SD = .35; G 2.1: $M = 4.44$, SD = .62; G 2.2: $M = 4.88$, SD = .35). The results confirmed that the design guidelines had been applied appropriately to the developed digital text.

4.3. Measures

The measures for this study consisted of a pretest, structure test, comprehension test and usability test. The pretest was adapted from Sung and Mayer (2012) to identify the homogeneity among the groups on prior knowledge in distance education, and consisted of 10 multiple-choice items. The pre-test was conducted to evaluate learners' knowledge such as characteristics of distance education, internet-based education, and strong points for the computer-mediated communication.

The structure test was designed to measure how well the students remembered the hierarchical relationships among the concepts and was adapted from Robinson (1993). The students were asked to outline the given digital text on a blank sheet of paper. They attempted to

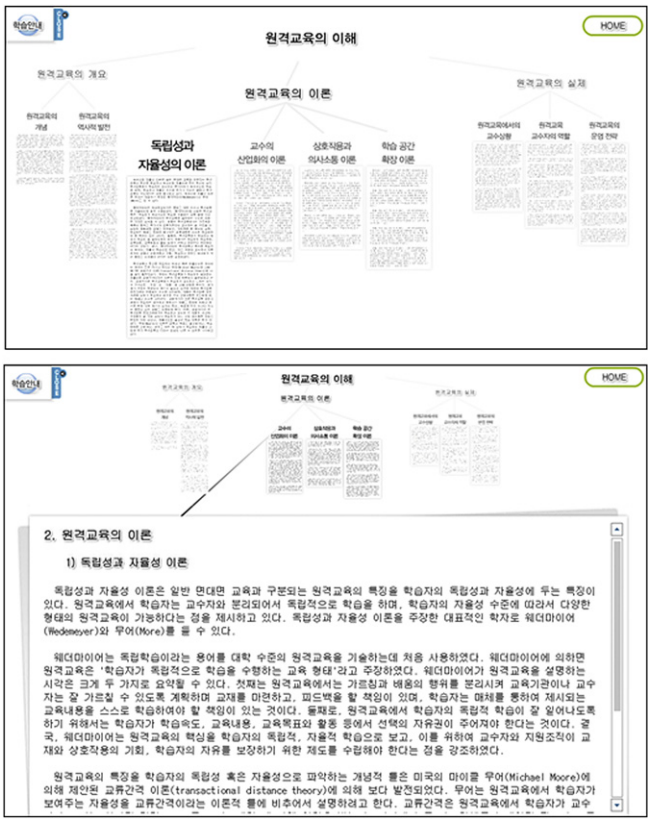


Fig. 3. Screenshots from the structure design type of digital text.

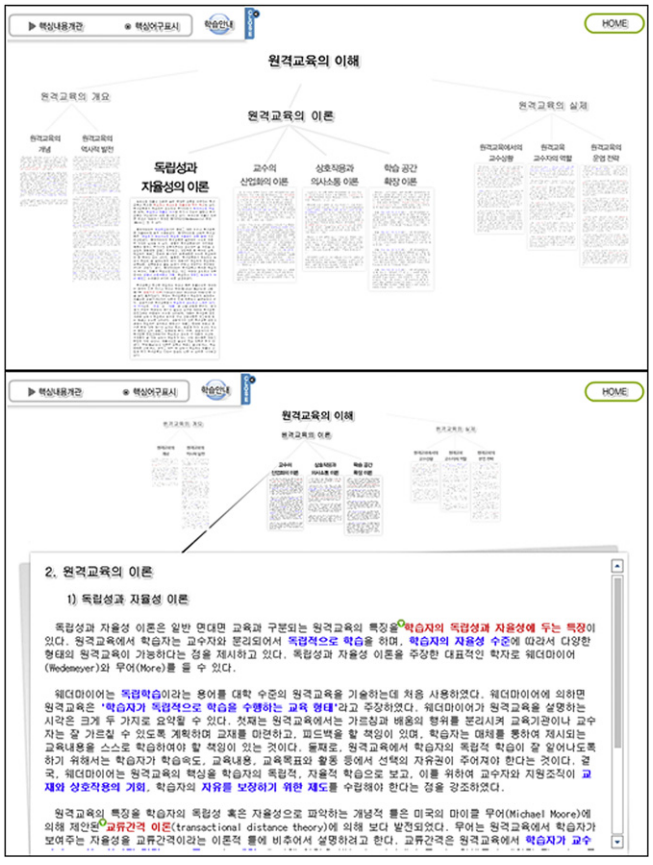


Fig. 4. Screenshots from the structure and selective-attention design type.

write down the main topics or headings and then to allocate subtopics under the main topics. One point was given for each of the three main topics and nine subtopics, yielding a score ranging from 0 to 12. For example, when writing down the main topic, i.e. the major theories of distance education, subtopics, such as the theories of independence and autonomy, theory of industrialization of teaching, transactional distance and communication, and expanded learning space, were scored one point with a total of five points. Writing down the topic with its equivalent words was given one point. The reliability coefficient based on Cronbach's alpha was .80, indicating suitable reliability.

The comprehension test was intended to measure how well the students understood the important information by reading the given digital text. The comprehension test items were reviewed by three experts for cross content validation, and some items were eliminated or revised based on the reviewer's comments. The test contained a total of 12 short-answers and 8 multiple-choice items. Of the 20 items, 10 were from the keywords or key phrases and the others from the non-emphasized areas according to selective-attention guidelines. Each correct answer received one point, yielding a score ranging from 0 to 20. The reliability coefficient based on Cronbach's alpha was .82, indicating suitable reliability. The sample short-answer item and multiple-choice item were as follows:

Explain in your own word what "transactional distance" means in the context of the "Theory of Transactional Distance" by Moore.

Which of the following is not correct regarding the definition of distance education?

a. Teachers and learners are in different places for all or most of the time.
b. Teachers and learners communicate through a range of technologies.
c. Collaborative learning is not possible with distance education.
d. Distance education is supported by administrative arrangements.

The usability test was developed by referring to Neilsen (1993) and Nokelainen (2006), and was assessed using the following four measuring scales: ease of use (3 items; $\alpha = .82$), awareness of the structure (5 items; $\alpha = .88$), content comprehension (5 items; $\alpha = .81$), and satisfaction with use (5 items; $\alpha = .94$), where α indicates the confidence level. The participants were asked to rate on a five-point likert-type scale (strongly disagree/strongly agree). The reliability coefficient of the entire questionnaire obtained by Cronbach's alpha was .95, which is suitable. The ease-of-use scale measures how easily the learners read and gain knowledge from the presented digital text. The sample items of this scale are as follows: 'I think that it is easy to read and learn', and 'I can easily understand how to use and operate this digital text'. The awareness of the structure scale measures the learners' perception of how much it helped them understand the given digital text structure. The sample items included 'I am aware of the entire structure at a glance with the given digital text', and 'I can easily memorize the entire structure with the given digital text.' The content comprehension scale measures the learner's perception on how helpful it was in improving their understanding of the core information of the presented digital text. The sample items included 'I am aware of the important materials at a glance with the given digital text', and 'I can easily memorize the important materials with the given digital text.' The satisfaction measures the degree to which the students felt satisfied by learning with the presented digital text, and the sample items were 'I think this digital text is more effective for reading and learning than the other digital text,' and 'I think this digital text is more efficient for reading and learning than the other digital text.'

4.4. Procedures

The experiment took place in a university computer laboratory. First, the students were assigned randomly to one of four groups and completed a pretest for 5 min. The results of the pre-test showed no significant difference in the students' prior knowledge (both applied: $M = 7.50$, SD = 1.47, structure: $M = 7.69$, SD = 1.26, selective-attention: $M = 8.12$, SD = 1.34, control: $M = 7.63$, SD = 1.37, $F = 1.347$, $p = .262$). Second, following an instruction, the students read and attempted to understand the given digital text for 20 min. Third, the students completed the structure test, comprehension test and usability test with all students finishing within 20 min.

4.5. Analysis

Two-way multivariate analysis of variance (MANOVA) was conducted to determine if the structure design guidelines or selective-attention design guidelines affect the structure test, comprehension test and usability test. The first and second factors were associated with applying the structure design guidelines and selective-attention design guidelines, respectively. The Levene's test of homogeneity, setting $\alpha = .05$, indicated that the error variances of the structure scores, comprehension scores, and usability scores were equal across the groups ($p > .05$). The effect sizes were measured using Cohen's d if a significant multivariate result was found. The effect size can be interpreted as follows: small $<.2$, medium $\sim .5$ and large $>.8$ (Cohen, 1988). Alpha was set to .05 for all statistical tests.

5. Results

Table 2 lists the means and standard deviations of the four groups on the three dependent variables (text structure comprehension, important content comprehension and usability ratings). The mean values for the structure test and comprehension test appeared to be high in the following order: both, structure, selective-attention and control groups. On the other hand, the mean values for the usability test showed a different order: both, selective-attention, structure and control groups.

5.1. Does the structure and/or selective-attention design guidelines enhance the learners' text comprehension?

5.1.1. Text structure comprehension

As shown in Table 2, the mean values of the groups that received the digital text with the structure design guidelines or the selective-attention design guidelines were higher than those of the groups that received the digital text with no guidelines on the structure test (Structure design guidelines: $M = 5.56$, SD = 2.60 vs. $M = 2.81$, SD = 2.05, $d = 1.35$; Selective-attention design guidelines: $M = 4.70$, SD = 2.85

Table 2
Mean score and standard deviation for four groups on the three dependent variables.

Dependent measures	Both design guidelines ($n = 36$)		Structure design guidelines ($n = 35$)		Selective-attention design guidelines ($n = 35$)		Control group ($n = 35$)		Main effect		Interaction effect
									Structure	Selective attention	
	M	SD	*M*	SD	*M*	SD	*M*	SD	*F* value *P* value *d*	*F* value *P* value *d*	*F* value *P* value
Structure[a]	6.04	2.74	5.07	2.38	3.31	2.25	2.30	1.69	50.179 .000 1.35	6.536 .012 .40	.003 .955
Comprehension[b]	13.75	2.79	11.94	3.00	11.28	3.31	10.46	2.90	15.208 .000 .64	6.771 .010 .44	.933 .336
Usability[c]	4.07	.41	3.80	.48	3.85	.38	2.37	.50	121.013 .000 .93	139.463 .000 1.00	65.299 .000
Ease of use	3.94	.46	3.81	.51	3.85	.43	2.42	.67	70.276 .000 .81	77.675 .000 .84	53.138 .000
Awareness of the structure	4.14	.56	4.05	.62	3.43	.50	2.39	.64	144.893 .000 1.51	33.489 .000 .55	23.312 .000
Content comprehension	4.20	.44	3.47	.56	4.10	.42	2.41	.58	46.287 .000 .59	201.957 .000 1.55	31.344 .000
Satisfaction of use	4.02	.53	3.86	.62	4.05	.60	2.25	.77	53.598 .000 .69	82.307 .000 .92	58.429 .000

[a] The range of scores was 0 ~ 12.
[b] The range of scores was 0 ~ 20.
[c] The range of scores was 0 ~ 5.

vs. $M = 3.69$, SD = 2.48, $d = .40$). Two-way MANOVA revealed significant overall effects for the structure and selective-attention design guidelines on the learners' text structure comprehension (Structure design guidelines: $F(1, 137) = 50.179$, $p = .000$, $\eta^2 = .268$; Selective-attention design guidelines: $F(1,137) = 6.536$, $p = .012$, $\eta^2 = .100$). On the other hand, no significant interaction was observed between applying the structure and the selective-attention design guidelines, suggesting that the effect of each treatment was addictive. The effect sizes for applying the structure design guideline, *d* values, were large, whereas those for applying the selective-attention design guidelines were medium. This suggests that the effects of the structure design guidelines on structure comprehension were greater than those of the selective-attention design guidelines.

5.1.2. Important contents comprehension

The mean values of the groups that received the digital text with the structure design guidelines or selective-attention design guidelines were also higher than the groups that had received the digital text with no guidelines on the comprehension test (Structure design guidelines: $M = 12.86$, SD = 3.02 vs. $M = 10.87$, SD = 3.12, $d = .64$; Selective-attention design guidelines: $M = 12.54$, SD = 3.28 vs. $M = 11.20$, SD = 3.02, $d = .44$). The main effects of applying the structure design guidelines ($F(1, 137) = 15.208$, $p = .000$, $\eta^2 = .100$) and selective-attention design guidelines ($F(1,137) = 6.771$, $p = .010$, $\eta^2 = .047$) were significant for the learners' important content comprehension. On the other hand, no significant interaction was observed between applying the structure and selective-attention design guidelines. The effect sizes, *d* values, for applying the structure design guidelines or selective-attention design guidelines were intermediate, suggesting that the effect of applying the selective-attention design guidelines on the learners' important context comprehension is equal to that of the structure design guidelines.

5.2. Does the structure and/or selective-attention design guidelines improve the learner ratings?

As shown in Table 2, the mean rating of the structure design groups or selective-attention design groups was significantly higher than that of the groups that received the digital text with no guidelines on the usability test (Structure design guidelines: $M = 3.94$, SD = .46 vs. $M = 3.11$, SD = .87, $d = .93$; Selective-attention design guidelines: $M = 3.97$, SD = .41 vs. $M = 3.08$, SD = .87, $d = 1.00$). MANOVA showed that the main effects of applying the structure design guidelines and applying selective-attention design guidelines reached statistical significance for the learners' usability ratings (Structure design guidelines: $F(1, 137) = 121.013$, $p = .000$, $\eta^2 = .469$; Selective-attention design guidelines: $F(1,137) = 139.463$, $p = .000$, $\eta^2 = .504$). A significant interaction was observed when applying the structure and selective-attention design guidelines, which are reflected in the observation that the control group gave much lower ratings than the three groups that studied the digital text with the visual design guidelines.

MANOVA revealed significant effects of applying the structure design guidelines to each of the four usability scales: ease of use, $F(1, 137) = 70.276$, $p = .000$, $\eta2 = .339$, awareness of the structure, $F(1, 137) = 144.893$, $p = .000$, $\eta2 = .514$, content comprehension, $F(1, 137) = 46.287$, $p = .000$, $\eta2 = .253$, and satisfaction of use, $F(1, 137) = 53.598$, $p = .000$, $\eta2 = .281$. MANOVA also revealed significant effects of applying the selective-attention design guidelines to each of the four usability scales: ease of use, $F(1, 137) = 77.675$, $p = .000$, $\eta2 = .362$,

awareness of the structure, $F(1, 137) = 33.489$, $p = .000$, $\eta 2 = .196$, content comprehension, $F(1, 137) = 201.957$, $p = .000$, $\eta 2 = .596$, and satisfaction of use, $F(1, 137) = 82.307$, $p = .000$, $\eta 2 = .375$. For each of the scales, there were significant interactions between applying the structure and selective-attention design guidelines. This shows that the control group gave much lower ratings than the three groups that studied using the digital text with the visual design guidelines. A follow-up pairwise Tukey test confirmed that the control group produced a lower mean rating on each of the usability scales than each of the other groups.

6. Discussion

6.1. Empirical contributions

The primary finding of this study is that the application of structure design guidelines to design digital text has a positive influence on the learner's comprehension of the text structure, comprehension of the important text contents and usability ratings. The structure design guidelines help the learners grasp and remember the structure of the text and the important information. The practical effects of this structure and content understanding have a positive effect on the perception of user-friendliness. The results of the effects of the structure design guidelines on the three dependent variables were similar to those reported by Kieras (1985), Lorch and Lorch (1996), Lorch, Lorch, and Inman (1993), Sung and Mayer (2012) and Surber and Schroeder (2007). Kieras (1985) suggested that the superficial structure information is essential for identifying not only the text structure but also the important contents. Organizational signals, such as headings, overview and topical summaries have effects on the learner's comprehension of the text structure and the text recall of important information (Lorch & Lorch, 1996; Surber & Schroeder, 2007). Sung and Mayer (2012) reported a significant effect on the text structure representation, comprehension and usability test using navigational aids in an e-lesson. According to previous studies, the structure design guidelines can serve as a cognitive guide and affective motive that help the learner comprehend the present digital text with satisfaction. No direct measures of cognitive processing were included in this study. Therefore, further research will be needed to examine the proposals that structure design guidelines guide learners (a) organize information from the presented digital text, (b) construct a type of mental representation for the text structure, and (c) navigate between the pages freely with unlimited accessibility.

These results also show that the selective-attention design guidelines has a significant effect on the learner's comprehension of the text structure, understanding of the key learning points and the effect on the usability ratings. The selective-attention design guidelines provide a guide to present the key phrases consecutively that helps the learners grasp the core information within a short period of time and understand the text structure by enabling them to find the connecting relationship in the overall contents. Furthermore, the new method, which presents character animation or collects the key phrases consecutively, helps the learner participate actively in the learning process by maintaining their interest in the learning materials. This supports the findings by Clark and Lyons (2004), Mohler, Osen, and Harrikari (2004), and Bachfischer and Robertson (2005). Previous studies suggested that presenting the key phrases using a kinetic typography technique affects not only the learner's attention but also makes the digital text more attractive (Clark & Lyons, 2004; Mohler et al., 2004). The selective-attention design guidelines were tested to determine if they affect learning from digital text in an effective and efficient manner with increased interest, but did not examine its direct relationship with the process of cognitive learning. Therefore, further research will be needed to determine if selective-attention design guidelines help learners (a) pay more attention to the digital text, (b) read digital text in an efficient manner, (c) preview or summarize and (d) make digital text attractive and entertaining.

6.2. Theoretical contributions

These results empirically support the Generative Theory of Mayer (2005) which adopts dual coding theory in a multimedia learning environment. The theory states that when learners are provided with verbal and visual information, they undergo the main information process of selecting, organizing and integrating to form meaning (Mayer, 2005). Among the information presented, the related words or images are selected to be formed in structure, and verbal and visual representations are integrated with prior knowledge. This is more effective in learning when both visual and verbal information are provided together instead of one type of information (Mayer, Heiser, & Lonn, 2001; Mayer & Moreno, 1998). Designing the digital text visually helps enhance understanding. Moreover, detecting the essential contents helps the learner read the text more easily. In addition, after the text is read and processed consecutively, the meaningful information is presented in such a form that the representation from a verbal model and visual model naturally form a referential relationship, which enhances text comprehension.

This theory appears to help expand the repository of conceptual models when instructional designers carry with digital text. As shown in Fig. 5, the instructional designers carry with digital text based on the conceptual model, and the learners read and understand the digital text depending on their mental model. The conceptual model is defined as an integrated concept for how the digital text is used, viewed and understood by the learner (Preece et al., 1994). The mental model of the learners is related to how digital text is comprehended by the learner's prior experience, which is already formed. This is explained by the principles of thought discovered by psychological researchers. Therefore, the conceptual model about the learners is most important in digital text design. This is because digital text can be designed with ease if the conceptual model regarding the users that the designer has is similar to the mental model of a learner. The visual design guidelines presented in this study can be considered congruent with the learner's mental model. This can be proven by the actual experimental results that applied the digital text guidelines, which enhanced the learner's understanding in both structure and content.

6.3. Practical contributions

Visual design guidelines were developed for digital text, which are dynamic, interactive and different from the printed text. In addition, they provide specific and effective methods for adapting visual perceptual principles as a psychological foundation to the design of dynamic and interactive digital text. From the perspective of designing digital text, this study suggests potential solutions for the problems that failed to utilize technology dynamics, interactivity and visualization beyond the existing similar design guidelines to those for printed text. Therefore, this study provides practical insights in terms of developing visual design guidelines that reflect the characteristics of digital text.

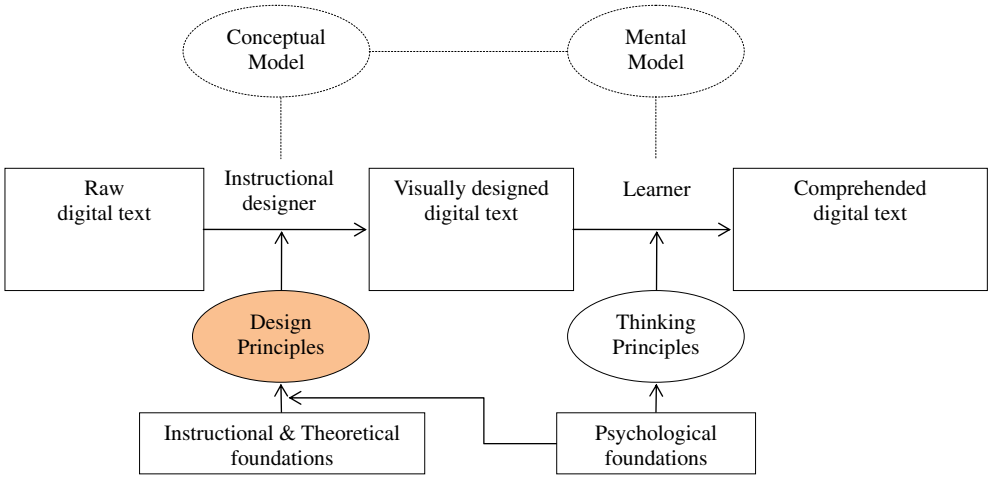


Fig. 5. Conceptual framework for designing and comprehending digital text.

7. Conclusion

This study developed visual design guidelines that can help learners understand the structure and the core contents based on psychological, instructional and technological foundations, which can affect the visual design of digital text, and validated their effectiveness. Two design guidelines to enhance structure understanding of the text were developed: 1) visualize the relationships between paragraphs and pages, and 2) visualize hierarchical structure between pages and present the selected page in the overall hierarchical structure context. Two design guidelines were developed to enhance the essential contents detection of the text: 1) visualize the meaning of keywords or key phrases with motion, and 2) present the keywords or key phrases in order. The validation from the 141 university students suggested that the visual design guidelines for structure and the essential contents have a positive influence on structure understanding, content comprehension and usability.

The structure design condition and the selective-attention design condition consisted of a collection of two guidelines. Therefore, future research will be needed to disentangle the effects of each of design guidelines used in this study. The digital text used in the study was approximately three thousand words. Accordingly, more study will be needed to adapt it to a much longer text. In addition, further validation with a cognitive mechanism embedded in visual design guidelines for digital text will be needed to confirm the effectiveness of the results.

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