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Effect of screen size on multimedia vocabulary learning

Daesang Kim and Dong-Joong Kim

Daesang Kim is an assistant professor in the Department of Business and Computer Information Systems at Saint Mary-of-the-Woods College. His main research interests are multimedia learning, technology-based learning, online learning, and course management systems. Address for correspondence: Daesang Kim, Guerin Hall, Saint Mary-of-the-Woods College, IN 47876 USA. Email: dkim@smwc.edu. Dong-Joong Kim is an assistant professor in the Department of Mathematics Education at Korea National University of Education. His research areas include the use of technologies to enhance learning and teaching. Address for correspondence: Dong-Joong Kim, Room 216 Applied Science Hall, 250 TaeseongTabyeon-ro, Gangnae-meyon, Cheongwon-gun, ChungBuk, The Republic of Korea. Email: djkim@knue.ac.kr

Abstract
The objective of this study was to investigate the effects of three different screen sizes (small, medium and large) and two types of multimedia instruction (text only and text with pictorial annotation) on vocabulary learning. One hundred thirty-five Korean middle school students learning English as a foreign language were randomly distributed into six groups and were given a pretest, a self-study multimedia instruction, a posttest and a retention test online. The pretest, posttest and retention test were identical and included 30 vocabulary questions. Results show that the large screen multimedia instruction helped the students to learn English vocabulary more effectively than the small screen instruction as demonstrated on both the posttest and retention test. However, there was little difference in vocabulary learning between the text-only and text-with-pictorial annotation instructions. Although visual perception can be influenced by each learner's expectations and knowledge, using a smaller screen for instruction causes more challenges for learners to perceive and comprehend vocabulary learning.

Introduction

Two-year-old Jonah watches his favourite movie, *Dinosaur*, on an 80-gig iPod in his living room. It is not surprising to see young children using small portable devices and even electronic toys as learning tools. Older children often view their favourite digital content (eg, movies, TV shows, news, books) on computers, iPods, e-book readers or cell phones. Students spend hours reading emails, blogs, text messages, news and reports. They even use various digital devices to complete school projects. Moreover, many newer portable devices enable their owners to view and create digital content online. Hearther (2008) notes that 'reading doesn't have to involve cover-to-cover, word-for-word activity' (p. 34). This reading trend requires educators and instructional material developers to change the way they use electronic content to teach young students. Such content often embraces text and graphics but also makes use of multimodal features including multimedia and hyperlinks (Larson, 2008). Many educators believe that all of these features should be taken into consideration when working with technology-based education.

Literature review

In this era of digital devices, mental processes are strongly related to tool-mediated activity (Vygotsky, 1986). Visual text and graphics are already popular tools in distance learning environments, where

graphics are often used to represent important information and support traditional text (Newby, Stepich, Lehman & Russell, 1996). The properties of such tools are inseparable from the cognitive information processes of the uses of the tools (Rogoff, 1990). Some researchers (Paivio, 1986; Sadoski & Paivio, 2001) believe that verbal stimuli (ie, visual text) and non-verbal stimuli (ie, graphics) are processed by the sensory systems. Other researchers have shown that higher cognitive processes occur when learners interact with verbal and nonverbal information (Mayer & Moreno, 2002; Schnotz, 2001, 2005). For example, Kim and Gilman (2008) adopted the cognitive theory of multimedia learning (CTML) from Mayer and Moreno (2002) to show that visual text (verbal) and graphics (non-verbal) enhanced the vocabulary learning performance of English as a foreign language (EFL) students better than visual text (verbal) and audio (verbal) in web-based instruction. Kim and Gilman explained that because many EFL learners are familiar with memorising new English vocabulary without knowing how the word is pronounced, audio creates an unnecessary distraction and thus requires a heavier cognitive load, as suggested by Sweller (Schnotz & Kürschner, 2007; Stiller, Freitag, Zinnbauer & Freitag, 2009; Sweller & Chandler, 1994; Sweller, van Merriënboer & Paas, 1998). However, adding graphics such as pictorial annotations in multimedia instruction is not always effective. For example, Schnotz, Bannert and Seufert (2002) argued that some learners paid less attention to visual text when pictures were added. Acha (2009) also found that children's vocabulary learning performance was better when they received verbal annotations than when they received either both verbal and pictorial annotations or pictorial annotations only. From the cognitive psychology perspective, most cognition involves a mixture of bottom-up processing (stimulus–attention–perception–thought processes–decision–response or action) and top-down processing, which is 'influenced by the individual's expectations and knowledge rather than simply by the stimulus itself' (Eysenck, 2001, p. 2). Although visual perception depends on the information that is presented to the eye and involves bottom-up processing, constructivist theorists emphasise the top-down process (Eysenck, 2001).

The growth of new technologies also demands a broader view of learning. In technology-enriched environments, learning occurs not only through interactive learning activities with others but also through the procedures of internalisation with the use of digital devices. Instances of learning through internalisation are illustrated by learning experiences that are shaped by computer-assisted instruction. In computer-assisted language learning, for instance, vocabulary learning has been facilitated through portable devices, the Internet and multimedia technology. Researchers have recently begun to investigate the use of various mobile technologies such as mobile phones, MP3 players and personal digital assistants for learning (Stockwell, 2007). An extensive amount of research on vocabulary learning via mobile phones has been conducted (eg, Chen, Hsieh & Kinshuk, 2008; Lu, 2008; Motiwalla, 2007). The findings of these studies suggest that mobile learning (m-learning) by means of these technologies has great potential in providing EFL learners with rich learning experiences anytime and anywhere (Lu, 2008). Cavus and Ibrahim (2009) claimed that students expressed their satisfaction and enjoyment of learning new English words with short message service text messaging through their mobile phones. These mobile devices that enhance communication and social interactions can be potential learning tools for language learners.

Rationale for the current study

Although mobile technologies that utilise wireless Internet connection could potentially make a difference in m-learning, the characteristics of small screens (eg, resolution, display size and text/image density) certainly create problematic challenges for the development of multimedia instruction. Most previous studies, which emphasised the importance of multimedia in learning, were conducted without comparing different display sizes. A few studies focusing on comparing different screen sizes have been conducted (Chen *et al*, 2003; Maniar, Bennett, Hand & Allan

2008; Reeves, Lang, Kim & Tatar 1999). For instance, some of the previous studies emphasising the importance of screen size were focused mainly on the effect of screen size on user attention. Reeves *et al* (1999) found that people tend to pay more attention when they receive a media message on a large screen. Chen *et al* (2003) raised a similar concern about screen size; that is, a small screen size may create problems with attention and visual perception. In a related study, Maniar *et al* (2008) stated that a small screen size may be problematic for learning paper folding through video-based instruction because the small space often displays less data at a given time and may create difficulties for users when they use the device for complex tasks. In spite of the interdependence of screen size and learning, there has been little investigation of the effects of screen size on students' vocabulary learning.

Students live in a rapidly changing and increasingly technological society where they may be exposed to numerous types of digital instruction. Because 'the human mind is limited in the amount of information it can process' (Miller, 1956, as cited by Sorden, 2005, p. 264), it is very important that educational researchers understand the effects of different screen sizes on multimedia vocabulary learning to reduce redundant memory load and to increase the effectiveness of instruction. The main focus of our study was to extend Kim and Gilman's (2008) experimental idea with three screen sizes (small, medium and large) and two types of multimedia instruction (text-only and text-with-pictorial annotation mode).

Method

Research questions

Our interest in investigating the effectiveness of screen size and two different instructions on students' vocabulary learning led to the following research questions:

1. What are the differences in vocabulary learning among students who received the small, medium and large computer screen multimedia instructions?
2. Is there a difference in vocabulary learning between the text-only and text-with-pictorial annotation mode of instruction?

Participants and materials

Five middle school classes in South Korea were recruited, yielding a sample of 135 students to participate voluntarily in the study during July 2009. Participants were randomly assigned to one of the six experimental groups in the study as shown in Table 1. We randomly assigned the numbers 1–6 to the participants in order to divide them into six groups. The retention test groups were smaller than the posttest groups because only students who took both the pretest and posttest were analysed for retention test results.

We adopted Kim and Gilman's (2008) instructional design with three common screen sizes (or screen resolutions): 320 × 240 pixels (small screen; eg, iPod), 480 × 320 pixels (medium screen; eg, smart phone) and 600 × 800 pixels (large screen; eg, Kindle). For each screen size, two representation modes were considered as the type of multimedia instruction: visual text only and visual text and pictorial annotation.

Table 1: Numbers of students in each group in pretest, posttest and retention test

Screen size	*Group*	*Pretest*	*Posttest*	*Retention test*
Small (320 × 240)	Text only	$n = 22$	$n = 20$	$n = 16$
	Text with pictorial annotation	$n = 22$	$n = 19$	$n = 14$
Medium (480 × 320)	Text only	$n = 23$	$n = 20$	$n = 15$
	Text with pictorial annotation	$n = 20$	$n = 23$	$n = 13$
Large (600 × 800)	Text only	$n = 21$	$n = 21$	$n = 16$
	Text with pictorial annotation	$n = 27$	$n = 27$	$n = 23$

The key design of the instruction was based on the following criteria:

- The items of English vocabulary were of appropriate difficulty level for Korean students.
- Pictorial annotations supported visual text.
- Pictorial annotations were available for cueing the meaning of vocabulary items from static or animated images.
- Example sentences were available for linguistic cues.

A web-based self-instruction programme was used for student vocabulary learning. The length of each lesson was a maximum of 30 minutes, and students controlled the amount of time they spent on each instruction.

Procedures

The experiment was conducted via the Internet. Students were required to take a pretest, participate in multimedia instruction, take a posttest and take a retention test for the study. The 30 vocabulary questions on the pretest, posttest and retention test were identical and were delivered in the same format. The pretest was administered to the participants approximately 1 week before they received the multimedia instruction. During the following week, the students received the self-study multimedia instruction based on their assigned groups. Items of vocabulary were projected on the computer screen through the multimedia instruction. Immediately after students finished the instruction, they were asked the same questions as in the pretest. Approximately 1 week after the posttest, the retention test, which contained the same questions as the posttest, was conducted.

Results

The analysis that follows is guided by the two research questions listed above.

Question 1: What are the differences in vocabulary learning among students who received the small, medium and large computer screen multimedia instructions?

The data were analysed to evaluate the difference of the small, medium and large screen sizes regardless of multimedia presentation modes as shown in Table 2. Analysis of variance (ANOVA) was conducted to determine if differences existed among the groups on the pretest, posttest and retention test. Scores on the pretest did not differ significantly across the screen size groups on a one-way ANOVA, $F(2, 132) = 0.61$ and $p = 0.544$. However, the comparison of the three groups showed a significant group difference, both in the posttest, $F(2, 127) = 11.34$, $p < 0.001$, and in the retention test, $F(2, 94) = 5.53$, $p < 0.01$. Eta squared (η^2) was also calculated as a measure of effect size. The resulting η^2 values in the posttest and retention test were 0.15 as a large effect and 0.11 as a medium effect respectively. Tukey's Honestly Significant Difference (HSD) test indicated that students who received the medium and large screen multimedia instructions earned higher scores than students who received the small screen instruction on the posttest and retention test. In the retention test, however, scores of students who studied content on the medium screen ($M = 14.71$) were not significantly better than those of students who studied content on the small screen ($M = 12.27$).

Table 2: One-way analysis of test scores of three different screen sizes on vocabulary learning

Test	*Small (screen size)*	*Medium (screen size)*	*Large (screen size)*	*F*	*p*
Pretest (mean score)	8.98	9.95	9.50	0.61	0.544
Posttest (mean score)	16.62	20.95	23.92	11.34	0.000*
Retention test (mean score)	12.27	14.71	18.87	5.53	0.005*

*The score difference is significant at the 0.01 level.

Table 3: Means of test scores with t-test results for two different instructions on vocabulary learning

Test	*Text only (mean score)*	*Text with graphics (mean score)*	*t-test*	*p*
Pretest (mean score)	9.09	9.84	1.60	0.208
Posttest (mean score)	19.57	21.78	0.12	0.729
Retention test (mean score)	14.68	16.52	0.48	0.490

Question 2: Is there a difference in vocabulary learning between the text-only and text-with-pictorial annotation mode of instruction?

In order to respond to the second research question, the data were separated into 'text-only' and 'text-with-pictorial annotation' groups. Table 3 shows that the overall difference between the two groups was also not significant. In other words, the performance of the visual text-only group and the text-with-pictorial annotation group was similar. In addition, each screen size group was separated into the text-only and text-with-pictorial annotation groups. The results of a *t*-test also revealed that there was no significant difference in the posttest between the two groups within the same screen size (small, medium and large).

Discussion

In this study, we sought to investigate the effects of three different screen sizes and two different modes of instruction on Korean EFL students' vocabulary learning. In sum, we identified the effects of screen size on multimedia vocabulary learning. More specifically, the mean of students who studied English vocabulary on the large screen was significantly higher than that of students who studied English vocabulary on the small screen. This difference was observed in both the posttest and retention test. Our findings also indicated that there was little difference between the text-only and text-with-pictorial annotation instruction on the same screen size.

Screen size

Our study shows that small screen instruction can be less effective in assisting Korean EFL students to learn and retain English vocabulary than large screen instruction. Figure 1 shows the cognitive process of vocabulary learning, which is modified from Mayer's CTML (Mayer 2001, p. 59). Although providing either text only or text and pictorial annotation allows learners to select relevant information (S), organise it into coherent representations (O) and integrate it with prior knowledge (I) as meaningful learning, showing the information on a small screen may lead to increased cognitive load.

Increased cognitive load (ie, extraneous cognitive load) may occur because the small screen (groups A and B) affects students' attention and visual perception (Chen *et al*, 2003; Maniar *et al*, 2008). This small screen effect can appear in the transition from sensory memory to working memory. For example, the small screen often shows information with limitations (ie, distortions in brightness, colour, font, and spacing between characters, lines, and words) compared to the large screen. In the cognitive process of vocabulary learning, learners must read the information closely and carefully and then try to translate it in a manner that is meaningful to them. When students receive words in visual text or pictorial annotations that 'gorge' means 'to eat greedily' on the small screen, they are easily distracted because the information with limits of the viewing screen does not have sufficient saliency and meaning to hold their attention, which may lead to perceptual errors. Moreover, spending too much time manipulating the environment itself by closely reading words or graphics on the screen may distract them from the concepts to be learned (eg, spelling and definition). Although visual perception can be

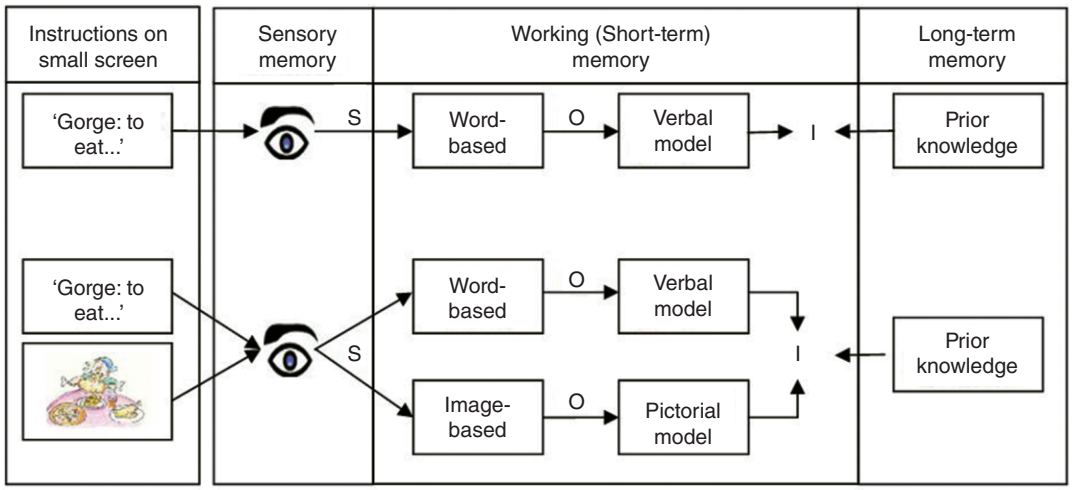

Figure 1: Framework of small screen vocabulary learning for EFL students. S, selecting; O, organising; I, integrating

influenced by each learner's expectations and knowledge, working memory activities can be overloaded by the limitations of the small screen before the learner gets to a series of information processing systems (eg, thinking process, decision and response or action) that enables meaningful retention of vocabulary.

Furthermore, the small screen may create obstacles in cognitive processes for users who are accustomed to learning on a bigger computer screen. For instance, some English definitions on the screen may not be translated correctly and their meanings may be distorted for students who are habituated to scanning information quickly rather than reading word by word on bigger computer screens. The scanning activity may make it difficult to perceive and comprehend vocabulary as students try to locate information rapidly by moving their eyes on the screen. Especially in the scanning process of an unrelated piece of information, students may often make careless mistakes and have difficulty in cognitive activities. One implication from our findings is that multimedia developers should consider perceptual errors and obstacles in cognitive processes in the use of small screens to reduce unnecessary memory load and increase the effectiveness of instruction.

Our findings suggest one more interesting consideration: that the limitations of small screen may have an effect on the nature of cognitive processes in working memory of vocabulary learning. According to Vygotsky (1986), 'the word is a direct expression of the historical nature of human consciousness' (p. 256). In other words, consciousness can be investigated in a word. In addition, thought and language in a word are inseparable. That is, the properties of language are inseparable from the thinking processes related to the word use (Rogoff, 1990). If one assumes that vocabulary learning is a tool-mediated activity, our findings can also indicate that screen size may affect not only language learning but also thinking processes and reasoning in language learning. In the domains of vocabulary learning, a bigger screen may effectively develop students' thinking process and reasoning because of its smaller cognitive load. Future researchers should take all components of cognitive load into consideration in assessing the outcomes of multimedia vocabulary learning. At the same time, there is a need to study how we can deal with all components to ensure a sound foundation on which to investigate thinking processes and reasoning in vocabulary learning.

Adding pictorial annotations

Adding pictorial annotations (ie, graphics) to visual text instruction has been recognised as an effective tool to represent information, but some researchers suggest that it does not easily generalise to all educational settings (eg, Schnotz & Kürschner, 2008; Tabbers, Martens & Merrienboer, 2004). In this study, although adding pictorial annotations increased most students' vocabulary learning on the medium and large screen sizes compared to the small screen, our findings suggest that there is no statistically significant difference between the visual text-only and visual text-and-pictorial annotation mode on the same screen size. Our results are closely related to the view of Chanlin (1997) that 'students who limited domain knowledge may regard graphics as excess complexities and incomprehensible information' (Stokes, 2002, p. 12). A definition of new vocabulary in text as a signifier may be directly signified to students, whereas a graphic is indirectly signified. For example, a graphic illustrating 'gorge' accompanying the definition of the word may overload cognitive processes for building its meaning ('to eat greedily') from both indirect graphic and direct word information. It seems that the added graphics for the Korean students led to extraneous load in the cognitive processes of multimedia vocabulary learning because visual attention is split between graphics (depictive representation) and visual text (descriptive representation), which have to be integrated mentally to achieve comprehension. Our study supports that adding pictures can have a negative effect on learning when the form of visualisation used affects mental model construction in an inappropriate way (Schnotz & Kürschner, 2008). From data on 135 Spanish EFL children, Acha (2009) also found that adding pictures may generate a higher cognitive load than presenting word-only instruction in a self-paced vocabulary learning multimedia programme. While EFL students are internalising meanings of new English words, adding pictorial annotations seems to create an excessive cognitive load.

Another possible reason for the insignificant difference between the two modes is Korean students' learning preference for visual text. Korean learners often focus on English vocabulary learning based on visual text alone in printed materials such as word lists or paired associates in which new words are presented with their translations (Kim & Gilman, 2008). As a result, many Korean students may have a higher verbal ability and lower visual ability to process information in computer-based vocabulary learning. Providing too many pictorial annotations can lead to increased cognitive load when students do not have high verbal and visual abilities (Chen *et al*, 2008). Furthermore, because the items in this study did not require high-order thinking processes, providing text-only instruction may be just as useful as adding pictorial annotations. Therefore, multimedia instruction developers need to be aware of cultural contexts when they add pictorial annotations because different cultures use such representations in different ways.

Limitations of the study

There are a few limitations of this study. First, this study was designed to investigate the effectiveness of screen size on a computer monitor rather than on mobile devices. Thus, the findings from this work may not be generalised to more interactive mobile learning, which can promote rich vocabulary learning experiences. However, they do provide important hypotheses for subsequent work. In addition, there are some limitations in the test instrument. The data of this study were based on repeated measurements using the same test. The results in the measurements should be interpreted with caution because of the possible familiarity of some questions to the students in the study. For instance, the students' familiarity and recognition of words in the repeated measures design may have affected test scores and even reduced the effectiveness of graphics in the results.

Conclusion

Although many researchers have found positive student attitudes towards vocabulary learning using small mobile devices, the findings of this study indicate that a small screen size can create

a high extraneous cognitive load regardless of different representation modes. Our results suggest that screen size should be considered in order to increase the effectiveness of multimedia instruction. One implication for teaching practice is that the content designed for a large screen size cannot be reduced to a small screen size without a change in learning effectiveness. Classroom teachers should consider the limitations of small screen size when they develop or redesign multimedia instruction by transforming current multimedia contents from a large screen to a small screen device and modify their instructional strategies as required such as by reducing the length of instruction or breaking down contents into small units. The limitations of a small screen may have an impact not only on students' perception of vocabulary learning, but also on other aspects of vocabulary learning such as thinking processes and reasoning—a fact that both researchers and practitioners of vocabulary learning should keep in mind.

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