

Effect of graphic design on E-book reading: A pilot eye-tracking study

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Abstract: This study explored graphical design effects on learner's E-book control, visual behaviors and learning performance by a pilot eye-tracking experiment. Twelve university students with novice experience of Spanish language participated in an e-book reading task to learn basic Spanish vocabularies. All participants were randomly assigned into two groups of reading materials with high-related graphics and low-related graphics. During the experiment, an ASL MobileEye eye tracker was used to track and record the gaze data of learners into video files. After reading 10 sets of text-and-graphic vocabularies in the E-book through an iPad, each participant received an immediately posttest, a three-days and a one-week delayed posttest. Each participant's action controls and visual paths on the e-book were observed and coded. Mann-Whitney U tests, Wilcoxon tests and Pearson's correlation analyses were used to analyze the data. Results showed that the high-related-graphic group had significant higher scores on immediately posttest. In addition, students gained learning retentions in both groups. Regarding e-book control behavior, the high-related-graphic group clicked on sound buttons more than the other group. The learners who had happier prior language learning experience also tended to click more on pronunciation buttons. Besides, the learners who believed that graphic is helpful for learning vocabularies spent less time reading the e-book. This pilot study successfully demonstrated the usability of eye-tracking techniques to investigate students' eye fixations while reading e-books. Future study is suggested to explore the effects of e-book content design on students' reading behaviors or learning outcomes.

Keywords: E-book, reading, iPad, eye tracking, control behavior

1. Introduction

1.1 E-books

Since tablet computer has higher performance monitor, interactive features and can be used with internet, it becomes popular these years. Many representation formats of multimedia is used in E-book, such as text, text-speech, music, sound and animation (Korat & Shamir, 2008). In terms of the features of E-book, it includes hidden button, quick view, keyword searching and bookmark (Vassiliou & Rowley, 2008). On the other hand, the content of E-book form mobile device is more flexible and interesting than the content on the printed material (Woody, Daniel & Baker, 2010). In addition, Lin (2009) found that text-speech, animation, audio effects and highlighting futures of E-book enhances motivation of student while foreign language reading. However, Lam, Lam, Lam and McNaught (2009) found that students didn't enjoy in E-book reading and had very low scores on comprehension tests. Those inconsistent findings suggests researcher to explore deeply in this field.

1.2 Cognitive theory of multimedia

Cognitive theory of multimedia reported by Mayer (2009) was based on Dual-coding theory of Paivio. Mayer believes multimedia helps learner effectively while the material designer understanding the learning process of human. Multimedia content includes graphic and text in the same time, which is visual information and verbal information. Because human have sense of auditory and sense of sight,

graphic and text observed from different sense and enter to working memory area, by learner constructs the relation between graphic and text actively, combine with prior knowledge, and add the new knowledge into long-term memory.

Mayer advanced Coherence Principle, he believes multimedia material helps learning while interesting but non-related graphic and text are excluded. In the past findings, researchers found that interesting material can improve learning outcomes. However, according to cognitive theory of multimedia, non-related material may distract learner's attention and waste learner's time on non-related graphic, reducing information process in working memory and increase cognitive overload. Second, it may break the causal relationship between knowledge. Third, it may increase learner to integrate non-related graphic and prior knowledge.

Based on Mayer's (2009) cognitive theory of multimedia, adding non-related material reduce performance of memory and transfer of learner. On the other hand, non-related material increase more negative effects to learner who has lower working memory and lack of prior knowledge. Accordingly, Mayer concluded that multimedia material without unneeded pictures could bring better learning outcome.

1.3 Eye movement and reading

In the beginning of 1990's, visual attention application of reading and information processing eye movement research developed gradually. Eye-fixation is the natural reaction of visual stimulation, therefore visual attention observation and eye movement records are the better ways to understand the mental processes of reading and other visual activity of learner. In the other word, visual attention plays an important role of information process of human (Rayner, 1998). Previous researchers dedicated to exam the relation between eye movement record, different animation, sign, speed of material design and learner's prior knowledge, most of them prove visual attention examination result bring the insight for reading and cognitive activity. The current paper is a pilot eye tracking study to understand the reading and controlling behaviors of learners while learning from the E-book.

2. Purpose

This study aimed at examining the effects of multimedia design on student E-book visual and control behavior, a pilot eye tracking examination was used in this study. Specifically, this study explored how two different designs of graphic in the E-book (i.e., high-related graphic of the Spanish vocabulary and low-related graphic of the vocabulary) effect learning performance (i.e., posttests for Spanish vocabulary) and visual and control behavior (i.e., the total number of pronunciation clicking, the total time of E-book reading and the count of inter-scanning). This study further explored the relation between learners' background and reading behavior. The research questions included in following: RQ1: What are the effects of E-book graphical design on students' immediately learning achievement, retention and delayed retention? RQ 2: Is there any significantly difference in students' E-book reading behaviors between high-related and low-related graphic groups? And, if necessary, RQ 3: Is there any significant relationship between learners' backgrounds and reading behaviors?

3. Methods

Participants

This study engaged in purposive sampling. Twelve participants of this study were selected from a university of north Taiwan, with almost having no experience in learning Spanish (only one male had learning experience for one semester), and were randomly assigned into high-related graphic group or low-related graphic group. Participants in Low-related graphic group read low-related-graphic Spanish vocabulary E-book, while participants in high-related group read high-related-graphic E-book. Numbers of participants in each group is six, with five male participants and seven female participants.

With two damaged eye-tracking record data of low-related group, the six data of high-related group and four data of low-related group was analyzed in this study.

Learning material

The learning material in this study was an E-book of ten Spanish color vocabularies. Mayer' (2009) s Coherence Principle stated that students got higher learning outcomes with combining related graphic with text. On the contrary, text with interesting but non-related graphic could reduce the memory of important content of learner, and the score of the transfer test was worse than the high-related one. Therefore, two versions of learning material in this study included ten color vocabularies as follows, rojo (red), rosa (pink), naranja (orange), Amarillo (yellow), azul (blue), morado (purple), verde (green), negro(black), gris(gray), and marrón(coffee). As shown in Figure1, since apple is red, the graphic is high-related to the vocabulary “rojo (red)”. On the contrary, In Figure 2, the graphic is a man doing gymnastics; therefore it is low-related to the vocabulary. Participants of high-related graphic group read the E-book with high-related graphic to the text, as shown in Figure1. Meanwhile, participants of low-related graphic group read low-related graphic to the text, as shown in Figure 2. The content of E-book was presented by iPad, ten vocabularies was shown on each page. Two groups were the same in vocabularies and graphics were different, that is, high-related graphic and low-related graphic.

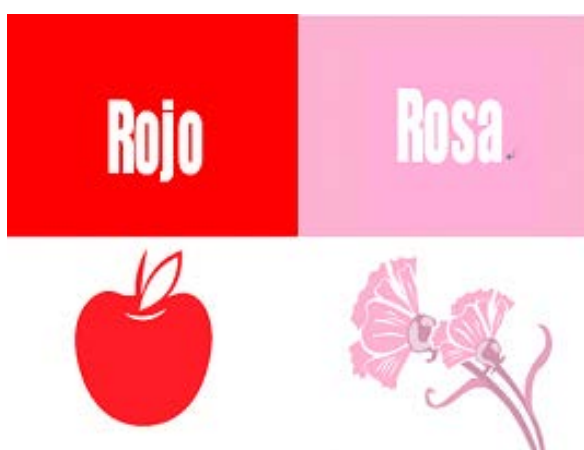


Figure1. Material for the high-related group.



Figure2. Material for the low-related group.

Eye-Tracking system

ASL Mobile Eye-XG with a sampling rate of 30 Hz was used to record participants' eye-movements through the reading process. It was free for participants to move their head. During the experiment, two cameras on the eye tracker recorded E-book control and reading behavior and participants' eye movement separately as the same time.

Background Questionnaire

The Background Questionnaire was developed for realizing the participants' language learning background; age, gender, the experiences and attitude of language learning, had experiences in learning Spanish or not, had experiences in using mobile devices assisting learning were included. The questionnaire was assessed through online Google docs questionnaire.

Posttest

The purpose of learning performance was to realize the differences of learning effect of participants between two groups after reading the material. Furthermore, to presume that if there was any difference learning effect between using high-related and low-related materials or not, the test question was edited by researcher and the professional Spanish teacher. There were twenty questions, and all questions were memory test, participants got five points for each correct answer. The content of the posttest was to

examine the vocabulary memory of participants. It separated into three parts: an immediately posttest and two delayed posttests after three days and one week after reading the material. All questions were distributed through online questionnaire with Google docs. The more scores the participants got, indicated the better learning effect they performed; the fewer scores they got, indicated the worse learning effect they performed.

Procedure

Twelve participants were randomly assigned into high-related graphic group and low-related graphic group. The procedure was:

1. Filled in the background questionnaire.
2. Wore the mobile-eye device and then processed calibration
3. Started to read Spanish color vocabulary E-book in iPad. The order of reading each page was not limited, and the maximum of total reading time is ten minutes.
4. After accomplish reading the E-book, participants received the first posttest immediately, the first delayed posttest is three days after reading the E-book; a week later, the second posttest was administered to participants.

Video Analyses

To observe E-book control and reading behavior of participants in different groups, the researchers counted two species of behavior by scenes video which included scan paths and gaze points from the eye tracker. Three behaviors were coding from videos, which were E-book control behavior and visual behaviors. The control behavior is total number of clicking pronunciation, which is defined as follows: the sum of participants' clicking on the pronunciation button in each page. On the other hand, visual behavior includes total reading time and inter-scanning count, which is defined as follows:

1. Total reading time: total time of participants to read the E-book.
2. Inter-scanning count: as shown in Figure 3, the cross mark means the gaze point of participant. While the cross mark on the text section, it indicates that the participant gaze at the text; in contrast, as shown in Figure 4, while the cross mark on the graphic section, it indicates that the participant gaze at the graphic. The scan path of "Text to graphic to text" or "text to graphic" was both counted as one time inter-scanning of text and graphic.

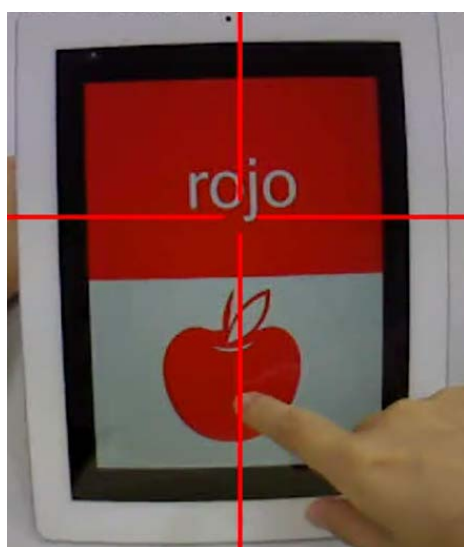


Figure 3. The participant gazes at the text.



Figure 4. The participant gazes at the graphic.

Statistical

In this study, Mann–Whitney U test was used to analysis the differences of three posttests and reading behavior between two groups. Besides, Wilcoxon test was used to analysis the retention of each posttest. Third, Pearson’s correlation was use to analysis participants’ background and reading behavior.

4. Results

Results of Mann–Whitney U test result on posttest scores

As shown in table 1, it’s found that there has high significantly different between high-related group and low-related group toward posttest1 and posttest2 scores (Cohen’s $d = 1.278$ and 1.111 respectively), the participants in high-related group get higher scores (Posttest1 mean = 91.25 , posttest2 mean = 88.75) than the participants in low-related group (Posttest1 mean = 75.00 , posttest2 mean = 71.25). In addition, the low significant different in the last posttest (Cohen’s $d = 0.474$), shows the scores of high-related group and low-related group are closer than both posttest1 and posttest2, the high-related group’s (Mean = 80.00) post-test2 scores is higher than the low-related group (Mean = 70.00). The mean of three posttests was shown in Figure 5; it means learners got lower scores on each posttests.

Table 1: Results of Mann–Whitney U test result on posttest scores between high and low related group.

	High-related			Low-related			z	p	Cohens’ d
	N	Mean	SD	N	Mean	SD			
Posttest1	4	91.25	11.09	4	75.00	14.14	-1.648	.099*	1.278 ^c
Posttest2	4	88.75	12.5	4	71.25	18.43	-1.423	.155	1.111 ^c
Posttest3	4	80.00	20.41	3	70.00	21.79	-0.178	.858	0.474 ^a

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Cohen’s d: ^a $0.2 < |d| < 0.5$; ^b $0.5 < |d| < 0.8$; ^c $0.8 < |d|$

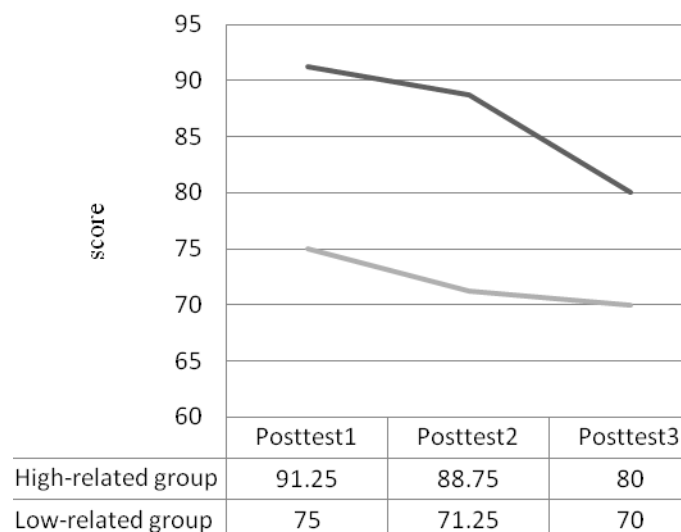


Figure 5. The line chart of average of three posttests.

Results of Wilcoxon test on posttest scores

As shown in Table 2 through the Wilcoxon test of different group found that there has no significant difference between high-related graphic group's and low-related graphic group's posttests. It indicated that the graphics of different relation have no significantly different toward learning retained.

Table 2: Results of Wilcoxon test on posttest scores.

	High-related					Low-related				
	N	Mean difference	SD	z	p	N	Mean difference	SD	z	p
Post1 - Post2	4	2.5	11.09	-1.414	.157	4	3.750	14.14	-.816	.414
Post2 - Post3	4	8.75	12.50	-1.604	.109	4	1.250	18.43	-1.342	.180
Post1 - Post3	4	11.25	20.41	-1.633	.102	3	5.000	21.80	-1.342	.180

*p < 0.1, **p < 0.05, ***p < 0.01

Results of Mann–Whitney U test result of E-book control and visual behavior

Table 3 and Figure 6 shows that different group Mann–Whitney U test result of reading behavior. It can be seen that pronunciation frequency of two groups have high significant difference (Cohen's d = 1.135). It indicates that the high-related group (Mean = 45.17) likes to click pronunciation better than the low-related group (Mean = 16.50). The high-related group trends to rely on clicking pronunciation. However, there is no difference between both total reading time and inter-scanning count in two groups.

Table 3: Results of Mann–Whitney U test result of E-book control and visual behavior.

	High-related				Low-related				z	p	Cohens' d
	N	Mean rank	Mean	SD	N	Mean rank	Mean	SD			
Total click number	6	6.67	45.17	34.5	4	3.75	16.50	9.15	-1.492	0.136	1.135 ^c
Total Reading Time	6	5.83	167.67	52.13	4	5.00	161.25	81.85	-.426	0.670	0.093
Inter-scanning count	6	5.50	40.00	17.16	4	5.50	39.25	13.72	0.000	1.000	0.048

*p < 0.1, **p < 0.05, ***p < 0.01

Cohen's d: ^a0.2 < |d| < 0.5; ^b0.5 < |d| < 0.8; ^c0.8 < |d|

Note: High-related = High-related group, Low-related = Low-related group

Total click number = the total number of clicking pronunciation, Total Reading Time = the total time of reading E-book,

Inter-scanning = the number of inter-scanning

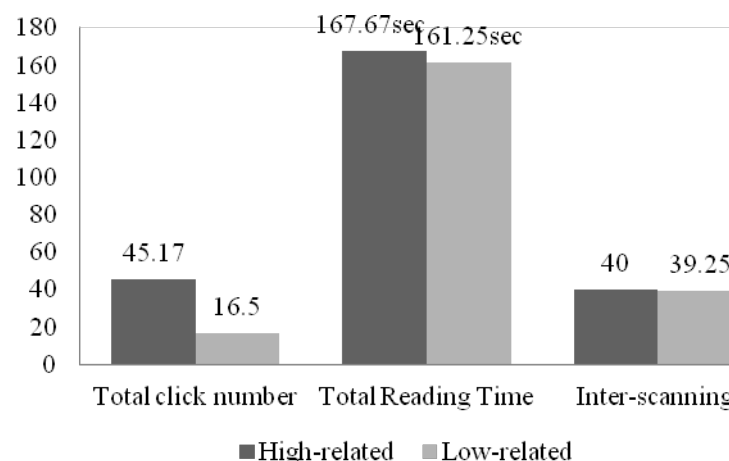


Figure 6. The column chart of average of three reading behaviors.

Correlation between participants' background and reading behavior

As shown in Table 4, happiness degree of learning English had significantly negative correlations with Pronunciation Frequency ($r=-0.723$, $p=.018$, $p<0.5$). This finding reveals that the students who have the happy experiences in learning English, they have lower frequency in click pronunciation. In other words, the participants who have the happy experiences in learning English seldom rely on sound resource.

In terms of, degree of how graphic helps while learning language had significantly negative correlations with Total Reading Time ($r=-0.671$, $p=.034$, $p<0.5$). It indicates that the participants of the opinion that graphics are useful for learning, they have less total reading time. On the contrary, the participants of the opinion that graphics aren't useful for learning, they have more total reading time.

Table 4: Correlation between participants' background and reading behavior.

	Happiness	TV	English Radio	Magazine	graphic helps
Total click number	-0.723**	0.181	0.323	0.060	-0.103
Total Reading Time	-0.393	0.123	-0.293	-0.399	-0.671**
Regression Frequency	-0.065	0.443	0.503	0.287	0.384

* $p < 0.1$, ** $p < 0.05$

Happiness= Happiness degree of learning English, TV= Frequency of watching English TV show, English Radio= Frequency of listing English Radio, Magazine= Frequency of reading English Magazine, graphic helps= Degree of how graphic helps while learning language

5. Discussion and conclusion

This study was conducted to investigate the effect of graphic design on E-book reading. We use Spanish vocabulary E-book as material, twelve adults was separated in high-related graphic group and low-related graphic group randomly. Three posttests scores and E-book control and visual behaviors—total number of clicking pronunciation, total time of reading E-book and the number of inter-scanning—was analysis. On the other hand, participants' background was also examined in the current study.

The first research question asked the effects of E-book graphical design on students' immediately learning achievement, retention and delayed retention. The result from Mann–Whitney U test showed that participants in high-related graphic group have not only significant higher score in immediately posttest but also in two delay posttests. This might imply that high-related graphic might be positive to learning outcome. This current finding is consistent to Mayer's (2009) Coherence Principle. On the other hand, Wilcoxon test analysis showed that there is no significant different in three posttests both in high-related graphic group and low-related graphic group. It could be inferred that the delayed retention wasn't be effect by different kinds of graphic.

The second research question asked is there any significantly difference in students' E-book reading behaviors between high-related and low-related graphic groups. The Mann–Whitney U test result showed that high-related graphic group has significant higher total number of clicking pronunciation. It might conjecture that high-related graphic could make more interaction when students read E-books.

The last research question asked is there any significant relationship between learners' backgrounds and reading behaviors. The correlation analysis result showed that participants who believe graphic is helpful while learning have significant lower total time of reading E-book. It might because that these graphics are learning paths for the participants who feel graphics are useful for learning, and they can grasp learning contents in less time. On the other hand, learners who had unhappy English learning experience have significant higher total number of clicking pronunciation.

In this study, the number of participants is small, future studies can further explore bigger samples to demonstrate the research result. Furthermore, the marital in the current study is language learning field, future study was suggested to explore different subjects.

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