Eye-tracking analyses of text-and-graphic design effects on E-book reading process and performance: "Spanish color vocabulary" as an example

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Abstract: This study aimed to explore how graphical design effects on learner's E-book control and visual behaviors by an eye-tracking experiment. The participants were twelve university students with novice experience of Spanish who were asked to read and learn basic Spanish vocabularies in E-book display on iPad. Participants were randomly assigned into two groups of reading materials with high-related graphics and low-related graphics. An ASL MobileEye eye tracker was used to track and record the gaze data of learners. Each participant's action of controls and visual attention during the experiment were observed and coded. Wilcoxon test, Mann–Whitney U tests and Pearson's correlation analyses were used to analyze the data. The results of this study suggest that low-related graphical design may reduce the effectiveness of learning. Future study is suggested to explore the effects of E-book cue design on students' visual attention and learning performance.

Keywords: E-book; eye tracking; visual attention; multimedia, reading

1. Introduction

1.1 E-books

Recently, since tablet computers are equipped with sundry features, such as touch screen, wireless networking capabilities and the storage of memory (Lim, Lee, and Ahn, 2013), it becomes popular in education field; therefore there has been much research about how it affect student's learning performance. E-book is a popular format to represent multimedia as the learning material; it includes text, text-speech, music, sound and animation (Korat, and Shamir, 2004). E-book also includes some features, such as hidden button, quick view, keyword searching and bookmark (Vassiliou, and Rowley, 2008). In terms of the content, E-book on mobile device is more flexible and interesting than the content on the printed material (Woody, Daniel, and Baker, 2010). Previous study compared the effect of read text in print and read on screen, the result showed that students who read E-books compared to printed texts had higher affective learning and psychomotor learning (Rockinson-Szapkiw, Courduff, Carter, and Bennett, 2013). However, another result of study found that students didn't enjoy in E-book reading and had very low scores on comprehension tests (Lam, Lam, Lam, and McNaught, 2009). Those inconsistent findings suggests researcher to explore deeply in this field.

1.2 Visual attention and reading behavior

Eye-fixation is the instinctive reaction of stimuli, therefore, visual attention analysis result may be the stronger evidence of mental processes of reading and other visual activity of learner (Rayner, 1998).

Visual attention is based on eye movement, and can be trace back to "eye-mind" assumption (Just, and Carpenter, 1976) which suggests that tracking one's eye movements could help people to realize his visual attention. Recently, eye tracking technology was started applying on cognitive process of

learning research to disclose how human process information while learning. Previous researchers divided different eye movement measures into three categories (Lai, et al.,2013):

•Temporal: to answer the "when" and "how long" questions related to cognitive processing.
•Spatial: to answer the "where" and "how" questions related to cognitive processing.
•Count: to show the importance of the visual content.

1.3 Cognitive theory of multimedia

According to dual-coding theory of Paivio, compare with single media, previous researcher found that multimedia may help learner effectively and enhance learning performance. Besides, in the past findings, researcher found that non-related material may distracts learner's attention and waste learner's time on non-related graphic, reducing information process in working memory and increase cognitive overload (Mayer, 2009).

2. Purpose

The aim of this study is to exam the effects of multimedia design on students' visual attention; researcher used an eye tracking examination in this study. Specifically, this study disclosed how two different design 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 attention (i.e., number of times zone observed, duration before first fixation arrival, percent time fixated related to total fixation, pupil size, total time in zone, fixation count, total fixation duration). This study further explored the relation between learners' background and reading behavior (i.e. total click number of pronunciation button). The research questions included in following:

RQ1: What is the rule of eye movement of different groups' learner's between text and graphic while E-book reading?

RQ2: Is there any significantly difference in students' E-book reading behaviors between high-related and low-related graphic groups?

RQ3: Is there any significant relationship between learners' visual attention and posttests?

3. Methods

3.1 Participants

Twelve university students form north Taiwan were novice Spanish learner were randomly assigned into high-related graphic group or low-related graphic group.

3.2 Learning material

Two versions E-book of Spanish vocabulary presented in iPad was used in this study, both version include ten pages with ten color vocabulary in each page. The high-related material as shown in Figure1, since apple is red, the graphic is high-related to the vocabulary "rojo (red)". On the other hand, in the

Figure1. Material for the high-related group.   Figure2. Material for the low-related group.

low-related graphic material (Figure2), the graphic of "rojo (red)" is a man doing gymnastics which is low-related to the vocabulary.

3.3 Eye-Tracking system

In this study, ASL Mobile Eye-XG with a sampling rate of 30 Hz was used to track participants' eye-movements through the experiment and Participants was free to move their head. During the experiment, participants' E-book control and eye movement was recorded separately as the same time.

3.4 Background Questionnaire

To realize participants' language learning experience, preferences, attitude and personal background, the background questionnaire was assessed before the reading task.

3.5 Posttest

To observe the effect of reading task, an immediately posttest (i.e., posttest1), a three day delayed posttest (i.e., posttest2) and a one week delayed posttest (i.e., posttest3) was assessed after the reading task. The better scores the participants had indicated the more learning content they remembered.

3.6 Reading behavior Analyses

According to prior literature (Lai, et al., 2013), E-book control behavior and several eye movement measures were observed, which are defined as follows:
● Total clicking number: the number of time that participant clicked the hidden bottom to listen the pronunciation of the vocabulary.
● Number of times zone observed: sum of visited fixations count and saccade count.
● Duration before first fixation arrival (seconds): time spent on the first fixation.
● Percent time fixated related to total fixation: total time spent on fixations in a look zone related to all look zone.
● Average pupil size (pixel2): the average size of pupil while looking in specific look zone.
● Total time in zone (seconds): sum of fixations saccade time in a look zone.
● Fixation count: total number of fixation counted in a look zone.
● Total fixation duration (seconds): total time spent on fixations

3.7 Statistical

Mann–Whitney U test was used to analysis the difference in students' E-book reading behaviors between high-related and low-related graphic groups. Besides, correlation analyses was used to analyses the relationship between learners' backgrounds and reading behaviors, as well as the relationship between learners' visual attention and posttests.

3.8 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

4.1 Resuls of Wilcoxon test on text and graphic

Though the Wilcoxon test, the findings showed that all eye movement measures of text and graphic were significant different with each other in low-related graphic group. However, in high-related graphic group, there was no significant different between text DBFFA (duration before first fixation arrival) and graphic DBFFA (p = 0.24). Meanwhile, in the high-related graphic group, the pupil size of text had no significant different to the pupil size of graphic (p = 0.46).

4.2 Results of Mann–Whitney U test result on visual attention

Though the Mann-Whitney U test, we found that low-related graphic group (mean = 13.16) had significant higher number of times zone observed (p = 0.02) compared to the high-related graphic group (mean = 7.10). It meant learner in low-related graphic group spent significant more time of observing the graphic zone than the high-related group.

4.3 Correlation between posttests and eye movement measures

The results of correlation between posttests and reading behavior showed that in high-related graphic group, the average pupil size was significantly negative related to the posttest1 (r = -.832, p = 0.040) and the posttest2 (r = -.882, p = 0.020).

In the low-related graphic group, the total fixation duration was significantly negative related to posttest1 (r = -0.820, p = 0.045), posttest2 (r = -0.895, p = 0.016) and posttest3 (r = -0.817, p = 0.047). The percent time fixated related to total fixation was significantly negative to posttest1 (r = -0.882, p = 0.02) and posttest2 (r = -0.852, p = 0.31). Total time in zone was significant negative to posttest2 (r = -0.860, p = 0.028). Fixation count was significantly negative to posttest2 (r = -0.867, p = 0.025).

These result may indicated that low-related graphic was unhelpful to the performance of learner.

5. Discussion and conclusion

This study was aimed to investigate the effect of graphic design on E-book reading behavior and learning performance. First, we found that learners who were in low-related graphic group had significant longer DBFFA on text zone than graphic zone, which may indicate learner who read low-related graphic thought the graphic is not helpful for them to memorize the content. Secondly, low-related graphic group spent more time observing the graphic zone, which is inconsistent with previous findings (Tsai, Hou, Lai, Liu, and Yang, 2012) (Balslev, et al., 2012) that learners fixated relevant information longer within text-based environment. Third, in the high-related graphic group, the smaller the students' pupil size is, the higher scores the students had. According to previous study (Seeber, and Kerzel, 2011), this result may indicated that when learners read high-related graphic, the cognitive load may be lower and could result in better learning efficiency. On the contrary, in the low-related graphic group, the more effort they spent on the graphic zone, the lower learning outcome they had. It may be indicate that low-related graphics created cognitive load to learners.

In sum, according to these findings and previous study (Mayer, 2009), relevant graphic and text is suggested to arrange in pairs while design vocabulary learning material. In other words, vocabulary learning material designers should be careful to selecting appropriate   graphics.

Future study was suggested to explore the relation between mental effort and pupil size of learner through interview method. In addition, more   complex cognitive test was suggested to assess learner's learning performance. Moreover, future study is suggested to explore the effects of E-book cue design on students' visual attention and learning performance

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