Instructional Effects on Students' Visual Attention in Game-based Science Learning

Li-Ju HUANG[a], Yi-Shiuan CHOU[a] & Meng-Jung TSAI[a*]
[a]*Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taiwan, ROC*
*mjtsai99@mail.ntust.edu.tw

Abstract: This study explored the instructional effects on students' visual attention allocations in game-based science learning by a pilot eye-tracking experiment. Seventeen university students with science or engineering backgrounds participated in a digital game for applying electromagnet concepts to solve problems. A video instruction was used as conceptual scaffolding for the experimental group. Students' eye movements were tracked and analyzed by FaceLab and GazeTracker software. Results showed that the video scaffolding successfully cued the students to focus on tools designed for problem solving. Besides, male and female students could have different reading preferences in game-based learning environments. Furthermore, the video scaffolding significantly impacted students' flow states in such a game-based learning environment; however, no significant gender difference was found regarding flow states. Future studies were also suggested in the paper.

Keywords: Eye tracking, game-based learning, science learning, scaffolding, flow

1. Introduction

Game-based learning is gradually noticed by educational researchers because it could lift learners' motivation to learn. There are six characteristics of game-based learning, which include rules, goals and objectives, outcomes and feedback, conflict/competition, interaction, and representation or story [1]. Those elements made let students have feelings in virtual situations, and also immerse in the learning environment and experience. And instructional designs or scaffoldings [2] for game-based learning are gradually noticed by recent researchers. However, how students interact with games cognitively is still not known in literature. Visual attention is the first stage for human beings to allocate and process information stimulated from environments. Hence, eye movements could reveal evidences of students' cognitive processes and have been analyzed a lot in research areas such as reading [3], scene viewing, visual search, human-computer interactions [4], and science problem solving [5]. However, research about the visual behaviors in game-based learning environments is still very limited. Therefore, this study was to examine the instructional (or scaffolding) effects on visual attention while playing a game to learn electromagnet concepts. Three research questions were examined here: First, what are the scaffolding effects on visual attention distributions in a web-based science learning environment? Second, is there any gender difference in visual distributions in a web-based science learning environment? Third, does any significant difference exist in the flow states between instructional groups and between genders?

2. Methods

2.1 Sample

To control the effect of background knowledge, 17 college freshmen who had taken fundamental science or engineering courses in a technology-oriented university were randomly selected as the sample of this pilot study. A total of 16 students, 9 males and 7 females, passed the eye-tracking calibrations and participated in the eye-tracking experiment. Then, they were randomly divided into two groups with mixed genders: One group received a video instruction before game playing (the scaffolding group, n=7) and the other did not have any video cues before game playing (the control group, n=9).

2.2 Instruments

2.2.1 Game Material

An educational game called *Escape the Lab*© [6] was used as a learning stimuli in the eye-tracking experiment conducted in this study. This game is about a researcher who was poisoned and locked in a lab. In this game, a student needs to play the role of the researcher and helps himself or herself to escape the lab. The critical point of the game is that the learners have to find and assemble electromagnet parts so that they can use the electromagnet to get the key for escaping the lab in 10 minutes. The operation of the game is only controlled with a mouse. This game had two interfaces (shown in Fig. 1), game-interface and book-interface. The main screen was game-interface that included the following four windows: Scene, Implement, Message and Time. The book-interface was loaded in screen when students clicked the book icon, and it included two areas: Book-Graphic and Book-Text.

2.2.2 Eye Tracker

This study used FaceLAB4.6 to record real time eye-movement data and collect participants' eye-movements with a sampling rate of 60 Hz. The stimuli were presented on a 22 inch monitor which was in front of participants at the distance approximately 75 cm. The digital game exhibited with a screen resolution of 1280×1027 pixels. GazeTracker8.0 was used to present experimental materials and analyze the fixation data.

2.2.3 Flow Survey

This paper used Killi's Flow Scale for Game [7] to measure subjects' flow states while playing the game. The questionnaire was scored on a 5-point Likert scale (5 = agree, 1 = disagree). The learners were asked to play *Escape the Lab*© (10 minutes) once, and then fill out the questionnaires. This scale included 9 dimensions (Challenge, Goal, Feedback, Control, Playability, Concentration, Time distortion, Autotelic experience, & Loss of self-consciousness) in flow experience and flow antecedents.

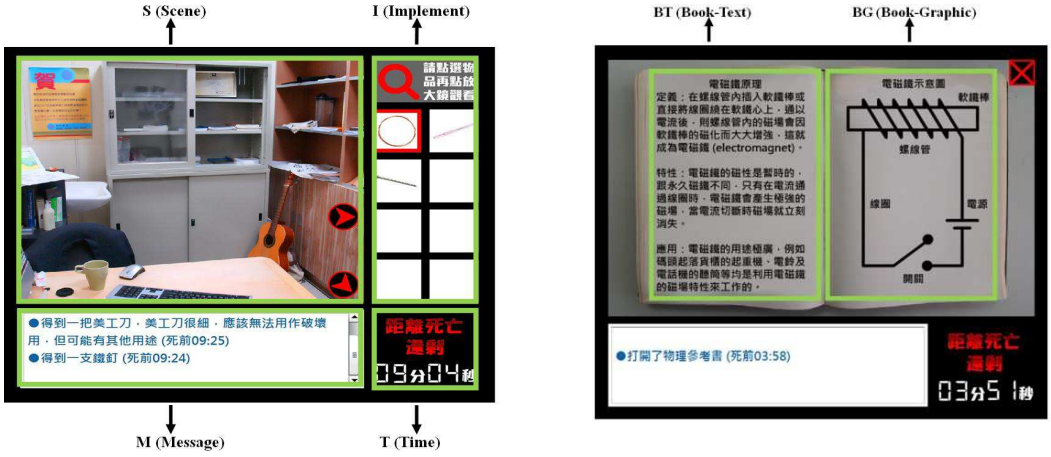
2.3 Treatment and Procedure

The treatment of this study was a 5 min video for a review of electromagnet rationales and applications, which were the key concepts to solve the problem and reach the goal designed in this game. There were three steps to conduct the experiment. First, the

participants were asked to write a pretest for prior knowledge and did the calibration for the eye trackers. Second, during the eye-tracking experiment, they had to solve the physics problem in 10 minutes while playing the digital game. Only the scaffolding group received the instructional treatment (i.e., the video) before playing the game. Finally, all of them were requested to write posttests and flow questionnaires. Each participant spent about 30 min engaged in the experiment process. Participants' eye-movement data and mouse clicking were recorded by Gaze Tracker 8.0.

2.4 Data Analyses

There were total 6 Look Zones defined for data analyses (shown in Fig. 1): S, I, M and T in the game-interface; BT and BG in the book-interface. Besides, the eye-tracking indices such as fixation count (FC), percent time spent in zone (PTSZ) and Percent time fixated related to total fixation duration (PTFT) for each students were collected and used for data analysis.



Game-interface Book- interface

Fig. 1. The definition two interfaces for Look Zones: Look Zone S= Scene; I= Implement; M= Message; T=Time; BG= Book-Graphic; BT= Book-Text.

3. Results

3.1 Visual attentions between scaffolding and control groups

The results of t-test showed that there were significant differences between scaffolding and control groups in the visual attention allocations within the Implement zones (i.e., the tool zones). The scaffolding groups had more FC ($t=3.30$, $p<0.01$), PTSZ ($t=3.49$, $p<0.01$) and PTFZ ($t=3.24$, $p<0.01$) than the control groups in Tool zones. Also, large effect sizes (Cohen's $d = 1.64$, 1.63 and 1.57, respectively) were found between the differences. That is, the students received scaffolding (a video-based prior knowledge instruction) looked more frequently, spent more time and concentrated more on the Implement Look Zone (i.e., the tool zones) than those students without any scaffolding before game playing. This means that the scaffolding video successfully cued the students to attend more on the critical tools for solving a science problem in a game-based learning environment.

3.2 Visual attentions between male and female students

This study compared students' visual attentions on each AOI in a book reading embedded in the game between genders. The book had two pages containing a graphic page and a text page. The graphic and text also provided as cues for making an electromagnet to solve the problem task of the game. A significant difference was found in Text Look Zone between genders. The female students had significantly higher FC ($t=-2.57$, $p<0.05$), PTSZ ($t=-2.48$, $p<0.05$) and PTFT ($t=-2.16$, $p<0.05$) than did the male students in Text Look Zone. And large effect sizes were also found in the differences (Cohen's $d = -1.26$, -1.23 and -1.07, respectively). The result showed that female students' visual attention distributions were focused more on the text readings than male students while playing the game. However, there were no significantly gender differences in graphic readings while playing the game. It appears that female students prefer to reading text when they seek help from the book designed in the game.

3.3 Flow comparisons between instructional groups and between genders

The results shows that the scaffolding group had a significant higher loss of self-consciousness than the control group ($t=2.60$, $p=.02<.05$). This indicated that the students who received a video instruction before playing the game immerged to the game deeper than those who did not received any scaffolding. On the other hand, the results show that most learners had positive flow states when they played the game. We also discovered that gender is no significant difference ($p=.29\sim.88$) in all flow dimensions. It means that males and females were no difference on flow states when they played this game.

4. Discussion

This study used eye-tracking technology to measure student's visual attentions between scaffolding and control groups in game-based science learning. Several pilot findings can be drawn from the results. First of all, scaffolding groups spent more time clicking tools areas than control groups. The scaffolding video-based instruction cued successfully students to try to focus on the tools designed in the game for construct an electromagnet. Future research can examine its impact on problem solving achievements or procedural knowledge gained from playing the game. Secondly, female students preferred to read texts when they seek for helps in games. Male students seemed to have no patient for reading text materials in game-based environments. This result is a little bit different from traditional reading research that students rely more on texts than graphics while reading multimedia stimuli, however, little gender difference was reported in studies in traditional labs or learning circumstances. Future studies can further explore the gender differences in preferences toward game-based learning environments. Finally, most learners had positive flow states when they played the game. We also found that there is no significant difference between genders in all flow dimensions. However, a significant difference between scaffolding and control groups was found in the loss of self-conscious dimension. This means that males and females both concentrated on the game, and the video-based conceptual scaffolding helps students immerse more deeply into the game. Future studies can examine the relationships between students' flow states and visual attention by eye-tracking methods.

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