An Examination of Prior Knowledge and Cueing Effects in an Animation

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Descriptors: multimedia learning, prior knowledge

Abstract

A 2 x 2 factorial design experimental study was conducted to investigate the effects of prior knowledge and visual cues in a complex animation on learning and metal effort. It also examined whether the effect of visual cueing is moderated by the prior knowledge. Data were collected from 102 undergraduate students from various majors in the Southwest University. The results showed that effects of cueing in a complex animation change depending on learners' level of prior knowledge. Specifically, low prior knowledge learners benefited more when visual cues were provided, whereas cues did not facilitate learning for high prior knowledge learners.

Theoretical Background

Multimedia learning environments have the ability to present the information in textual, graphical, and audible forms (Mayer, 2001). This allowed the instructional designers to create more effective and richer learning environments. However, the design of multimedia instruction is crucial in order to provide effective instruction to the learners. According to multimedia principle, people learn better when the information is presented with text and pictures than with words alone (Mayer, 2005). In some situations, using only words with pictures is not necessary to enhance the learning. According to Cognitive Load Theory (CLT) and Cognitive Theory of Multimedia Learning (CTML), the human mind has limited capacity of processing the information in the working memory at the same time (Mayer, 2001; Sweller, 2005; Sweller, van Merrienboer & Pass, 1998). Therefore, only presenting the information with multiple modalities is not enough to ensure the superior performance when we consider the limitations of the human cognitive system (Ginns, 2005; Sweller et al., 1998). As an initiative to ensure the superior performance in multimedia learning environments, recent research studies have begun to focus on the use of strategies to reduce extraneous cognitive load and enhance the intrinsic cognitive load.

With the advances in the computer technology and software, instructional designers have been widely used to create more effective and interactive learning environments to help the learners enhance their recall of complex dynamic systems and their understanding of the materials (Lowe, 2004). Animations provide several advantages, such as increasing interactivity of instructional materials, enhancing engagement, object trajectory, depicting motion and making abstract information concrete (Betrancourt, 2005). However, including animations in multimedia learning environments is not enough by itself to ensure superior performance unless we consider the limitations of the human cognitive system.

Figure 1 represents the human information-processing system according to the CTML. It is represented as a series of boxes and arrows. The big rectangular boxes indicate the memory stores that are sensory memory, working memory and long term memory. Two rows represent the dual-channels, with the auditory/verbal channel in the first row and visual/pictorial channel at the bottom. The arrows represent the cognitive processes. The arrow from word to eye indicates the action of the printed text entering through the eyes.

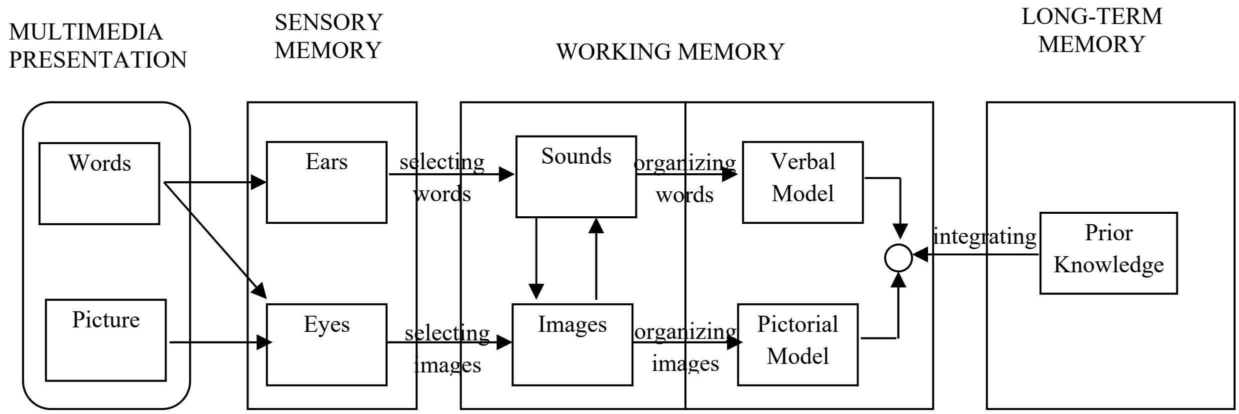

Figure 1. Cognitive theory of multimedia learning. Adapted from Multimedia learning (p.61), by R.E. Mayer, 2009,New York: Cambridge University Press. Copyright 2009 by the Cambridge University Press. Adapted with permission.

CTML defines five cognitive processes which are required for meaningful learning to occur animation with narration. These are selecting relevant words, selecting relevant images, organizing selected words, organizing selected images and integrating word-based and image-based representations (Mayer, 2009). Due to the limited capacity of the working memory, it is essential to select relevant words and images to process. The learner is responsible for judging the images and words and choosing the most relevant one in order to understand the presented information. However, learners might difficulty in selecting the essential information from the visual display which corresponds to the narration within a limited time due to the transience nature of the animation. Learners are required to keep the narrated information in the Working Memory (WM) while searching to the relevant information from the visual. This causes a cognitive load in the WM. Moreover, learner might miss the information, if they cannot find the relevant information within a limited time. Therefore, educational researchers have paid considerable amount of attention to learning from animations (Ploetzner & Lowe, 2004).

To make animations effective for learning, the cognitive load caused by the transience should be counteracted. Several researchers (Boucheix, Lowe, Putri & Groff, 2013; Sheiter & Eitel, 2015) have stressed the importance of guiding learners' attention to the relevant information in animation. This can be done by the use of cues. Cueing guides the learner's cognitive processing, helps the learner to select the relevant information, organize the information logically, and integrates the information with prior knowledge by providing cues (Mautone & Mayer, 2001).

Besides cueing, individual difference needs to be considered in instructional design (Betrancourt, 2005; Kalyuga, 2009; Kalyuga, 2014; Mayer, 2001). Henderson (2003) stressed that prior knowledge in the long-term memory (LTM) can control the learners; visual attention. "The selection of essential visual information of a display depends not only on the manner in which the information is presented, but also on the quantity and specificity of the pre-existing knowledge" (Khacharem, 2016, p.2). Prior knowledge plays an important role on distinguishing the relevant and irrelevant information, so it helps the learners to direct their attention to the essential information (Jarodzka, Scheiter, Gerjets, & van Gog, 2010). Expertise reversal effect also stressed that design principles that are effective for low-knowledge learners may not help or hinder high-knowledge learners (Kalyuga, 2014).

Guidance effect of cueing have been highlighted by several research studies (e.g., Ozcelik, Arslan-Ari, & Cagiltay, 2010; Jamet, 2014). However, there are limited number of studies examining the interaction between prior knowledge and cueing, which is one of the limitations of cueing research in multimedia learning (Richter, Scheiter & Eitel, 2016). Though few studies (Johnson, Ozogul, & Reisslein, 2015; Khacharem, 2016) found a significant interaction effect when cues were provided with the features of animated pedagogical agents and arrows in a static diagram, very little is known whether visual cueing in a narrated animation interact with prior knowledge to affect learning. Thus, the purpose of this study was to examine the effects of prior knowledge and visual cueing in a complex animation on learning and mental effort. It also investigated whether the effect of visual cueing is moderated by the prior knowledge.

Methodology

A total of 102 volunteer undergraduate students from various majors in a large Southwestern university participated in the study. To categorize the participants as low prior knowledge (LPK) and high prior knowledge (HPK), 33th and 66th percentiles of their prior knowledge scores were used as cut-offs. The students whose prior knowledge scores were in the 33th percentile or below were assigned to a LPK group (n=36) whereas the students whose prior knowledge scores were in the 66th percentile or above were assigned to a HPK group (n=37). Therefore, only 73 participants (39 females, 34 males) were included in the data analysis. Their ages ranged from 18 to 34 with a mean of 20.34 and standard deviation of 2.81. An independent t-test revealed that the prior knowledge of two groups were significantly different, t (71) = - 29.32, p<.01.

Participants were randomly assigned to either no cueing (n =36) or visual cueing (n =37) conditions. This resulted in four experimental groups: no cueing/LPK (n=19), no cueing/HPK (n=19), visual cueing/LPK (n=17), and visual cueing/HPK (n=20).

Two versions of an instructional material about photosynthesis, light dependent and light independent reactions were used. The content was adapted from a college level plant biology textbook presented with four separate animation. The cued animation was identical to the uncued one except the presence of the visual cues (see Figure 2). The animations took totally 9 minutes and 47 seconds. In cued animation, each corresponding terminological label (e.g. Photosystem I, P700, plasocyanin) became red during the narration of the sentence in which the item was mentioned. After each animation, two buttons, "Continue" and "Replay", appeared. The learners were not allowed to go backward or to skip around within the program.

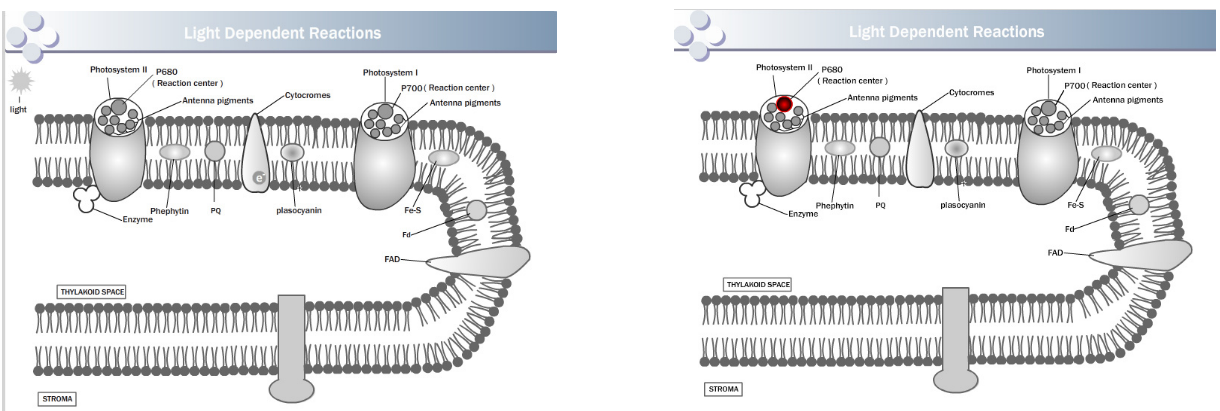

Figure 2. Sample screenshot of no cueing (*left*) and visual cueing (*right*) conditions/

This experimental study was conducted in a computer laboratory (15-24 participants per session). After the participants were given introductory information about the study, they were asked to complete a demographic questionnaire and prior knowledge test. Then, they studied the instructional material at their own pace and completed the computer-based tests consisting of the mental load scale, retention test, the transfer test, and the matching test sequentially. There was no time limit to study the material and to complete the tests.

Results & Discussion

A two-way MANOVA was conducted to determine the effects of prior knowledge and cueing on retention, transfer and matching. MANOVA revealed a nonsignificant main effect for cueing (*Wilks's* = .99, F(3, 67) = .23, p = .88) and a significant main effect for prior knowledge (*Wilks's* = .880, F(3,67) = 5.75, p < .05, ^{2} = .21). However, the interaction between prior knowledge and cueing was also significant (*Wilks's* = .84, F(3, 67) = 4.14, p < .05, ^{2} = .17). Given multivariate significance, the univariate effects were examined. Univariate testing indicated this interaction to be significant for transfer (F (1,69) =6.93, p<.05, η^2 = .06) and matching (F (1,67) =5.38, p<.05, η^2 = .07.

Follow-up pairwise comparisons indicated that LPK learners in the visual cueing group had significantly higher transfer scores than the LPK students in the no cueing group, p< .05. Although there was no significant difference in matching scores, the examination of the mean scores indicated that LPK learners in the visual cueing (M=55.66) outperformed those in the no cueing group (M=44.42) on the matching test.

For HPK learners, matching (p=.35) and transfer scores (p=.17) did not significantly differ between no cueing and visual cueing groups. However, HPK learners did better on the transfer and matching test when the animation does not include cues.

When there was no cueing, HPK learners had significantly higher matching and transfer scores compared to LPK learners, $p<.05$. However, when visual cues were introduced, although it is not statistically significant, LPK learners had higher transfer and matching scores than HPK learners.

The follow-up univariate tests' results revealed a nonsignificant interaction effect on retention $F(1,69) = .07$, $p = .79$.

The results of the two-way ANOVA revealed that there were no significant effects of prior knowledge ($F(1,69) = .94$, $p = .34$), cueing ($F(1,69) = .17$, $p = .69$), or interaction effect ($F(1,69) = .22$, $p = .64$) on mental effort.

These results indicated the moderating effects of prior knowledge on the impact of cueing in learning from instructional animations. In this study, LPK learners benefited more from cueing. The findings are consistent with the expertise reversal principle that emphasizes instructional design principles for multimedia learning which enhance LPK learners' performance may not be equally effective for HPK learners (Kalyuga, 2014). These design strategies may even hinder the performance of high prior knowledge learners. Providing external visual guidance in an animation might impose an unnecessary load on the WM of high prior knowledge learners and diminish resources necessary to gain and integrate new information because they still need to relate the existing knowledge base with externally provided guidance (Kalyuga, 2008).

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