Interactive Learning Environments

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/nile20

Effects of visual cues and self-explanation prompts: empirical evidence in a multimedia environment

Lijia Lin\textsuperscript{a}, Robert K. Atkinson\textsuperscript{b}, Wilhelmina C. Savenye\textsuperscript{c} & Brian C. Nelson\textsuperscript{b}

\textsuperscript{a} Key Laboratory of Brain Functional Genomics (MOE & STCSM), Institute of Cognitive Neuroscience, School of Psychology and Cognitive Science, East China Normal University, Shanghai, People’s Republic of China

\textsuperscript{b} School of Computing, Informatics, and Decision Systems Engineering, Arizona State University, Tempe, AZ, USA

\textsuperscript{c} Mary Lou Fulton Teachers College, Arizona State University, Tempe, AZ, USA

Published online: 12 Jun 2014.

To cite this article: Lijia Lin, Robert K. Atkinson, Wilhelmina C. Savenye & Brian C. Nelson (2014): Effects of visual cues and self-explanation prompts: empirical evidence in a multimedia environment, Interactive Learning Environments, DOI: 10.1080/10494820.2014.924531

To link to this article: http://dx.doi.org/10.1080/10494820.2014.924531

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the “Content”) contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing,
Effects of visual cues and self-explanation prompts: empirical evidence in a multimedia environment

Lijia Lin, Robert K. Atkinson, Wilhelmina C. Savenye and Brian C. Nelson

The purpose of this study was to investigate the impacts of visual cues and different types of self-explanation prompts on learning, cognitive load, and intrinsic motivation in an interactive multimedia environment that was designed to deliver a computer-based lesson about the human cardiovascular system. A total of 126 college students were randomly assigned in equal numbers (N = 21) to one of the six conditions in a 2 × 3 factorial design with visual cueing (cueing vs. no cueing) and type of self-explanation prompts (prediction prompts vs. reflection prompts vs. no prompts) as the between-subjects factors. The results revealed that (a) participants presented with cued animations had significantly higher learning outcome scores than their peers who viewed uncued animations, and (b) cognitive load and intrinsic motivation had different impacts on learning outcomes due to the moderation effect of cueing. The results suggest that the cues may not only enhance learning, but also indirectly impact learning, cognitive load, and intrinsic motivation.

Keywords: visual cueing; multimedia learning; self-explanation prompt; cognitive load; intrinsic motivation

Introduction

Cognitive load theory (CLT, Paas, Renkl, & Sweller, 2003; Schnitz & Kurschner, 2007; Sweller, van Merriënboer, & Paas, 1998) and cognitive theory of multimedia learning (CTML, Mayer, 2005) emphasize the cognitive processes of learning. Three types of cognitive processing that impose three types of mental effort on humans’ working memory may occur during learning in multimedia environments. Mental effort imposed on learners may be due to the inherent nature of the learning materials (intrinsic load), may be irrelevant and harmful to learning due to inappropriate instructional design (extraneous load), or may lead learners to make sense of the materials and schema construction (germane load).

Contemporary researchers have attempted to incorporate motivation into their theoretical models. Several researchers (Brünken, Plass, & Moreno, 2010; Moreno, 2009; Moreno & Mayer, 2007) have extended CTML to cognitive-affective theory of learning with media
(CATLM) by specifying motivation as a factor that mediates learning and cognitive engagement. Mayer (2009, 2014) further pointed out that motivational features in instructional design can contribute to germane processing and germane load, which aids learners in making sense of the essential material. However, Leutner (2014) suggested a potential moderating role of motivation in multimedia learning. Building on this research in the current study, we investigated learning outcomes, cognitive load and intrinsic motivation in a learning environment where visual cues and self-explanation prompts were provided to undergraduate students to support their learning.

**Cueing as an aid for animations**

Visual cues are non-content devices to direct learners’ attention to the thematically important information on visual displays. Empirical research has shown that cueing is effective to direct learners’ attention (de Koning, Tabbers, Rikers, & Paas, 2009, 2010a; Ozcelik, Arslan-Ari, & Cagiltay, 2010; Ozcelik, Karakus, Kursun, & Cagiltay, 2009) and to enhance learning by reducing irrelevant visual search activities (Amadieu, Mariné, & Laimay, 2011; Boucheix & Guignard, 2005; Jamet, Gavota, & Quaireau, 2008; Jeung, Chandler, & Sweller, 1997; Kalyuga, Chandler, & Sweller, 1999; de Koning, Tabbers, Rikers, & Paas, 2007, 2010c; Lin & Atkinson, 2011; for reviews, see Mayer & Moreno, 2003; Wouters, Paas, & van Merriënboer, 2009). For instance, de Koning et al. (2007) conducted a study to investigate the effectiveness of a cued animated cardiovascular system. The results showed that the participants in the cued animated condition had significantly higher scores on both comprehension and transfer tests than their peers in the uncued conditions. Similarly, Lin and Atkinson (2011) found that using arrows as visual cues promoted more efficient learning of the rock cycle than using no cues. However, the results of two other studies revealed that cueing was not effective when combined with cued narrations (Mautone & Mayer, 2001) or it was only effective for several seconds before the effect disappeared (Lowe & Boucheix, 2011). These empirical results make the effectiveness of cueing still questionable. In terms of motivation, rarely have researchers looked into the cueing effect within the motivation framework. Plass, Heidig, Hayward, Homer, and Um (2014) found that, compared to gray visuals, warm-color-cued visuals enhanced comprehension, but not cognitive load or intrinsic motivation. However, this finding is confounded as the potential effects of other elements cannot be disentangled.

**Prompting self-explanation to support learning**

Successfully directing learners’ attention to the important information cannot guarantee enhanced learning, as cueing may facilitate learners’ attention but not learners’ engagement (de Koning et al., 2009). Prompting self-explanation is an instructional aid that has the potential to engage learners in deep learning (Roy & Chi, 2005) and foster germane load. The literature provides some evidence to support the effectiveness of self-explanation prompts implemented in multimedia environments (Atkinson, Renkl, & Merrill, 2003; Berthold, Eysink, & Renkl, 2009; Berthold & Renkl, 2009; Mayer, Dow, & Mayer, 2003). From a motivational perspective, Mayer (2009) pointed out that motivation may be attributable to germane processing in multimedia learning, but this relationship remains ambiguous as it lacks empirical evidence.

When self-explanation prompts are implemented by computer-based programs, the issue of when to implement prompts during instruction arises. Several empirical studies (Hegarty, Kriz, & Cate, 2003; Mayer et al., 2003; Moreno, 2009) investigated prediction...
prompts – presenting prompting questions right before the related instruction was delivered. The rationale for implementing prediction prompts is that learners’ prior knowledge may be activated by these prompts, which facilitates the integration of incoming information with existing knowledge. The results of some studies revealed the benefits of the prediction prompts compared to no prompts. For instance, Hegarty et al. (2003) provided learners with five prediction questions before the learners viewed an animated or static graphical representation of a mechanical system. They found in two experiments that these prediction questions had a positive and significant impact on learners’ understanding of the system.

Reflection prompts – questions that ask learners to explain immediately after the related instruction – are another type of prompt that can be used for self-explanation. The rationale behind the use of reflection prompts is that reflection-induced self-explanations can foster deep learning (Moreno & Mayer, 2010) and learners will focus on their own thoughts and question what they have learned during reflection (Lin & Lehman, 1999; Rosenshine, Meister, & Chapman, 1996). Moreno and Mayer (2005) investigated the cognitive function of reflection prompts along with guidance in a multimedia game augmented with an animated pedagogical agent. They found that there was a reflection-prompt effect on retention and transfer tests in a non-interactive environment, but there was no effect in an interactive environment. It is of note that past research has only investigated learning and cognitive benefits of self-explanation prompts compared to no prompts. No empirical study has delved into the issue of when to implement self-explanation prompts.

Overview of the study

We conducted the current study to investigate the potential impacts of two instructional manipulations – visual cueing vs. no cueing and prediction prompts vs. reflection prompts vs. no prompts – in an interactive multimedia environment that delivered a lesson about the human cardiovascular system. Specifically, this study addressed the following research questions:

(a) Is cueing effective in positively influencing cognitive load and enhancing learning outcomes?
(b) Do different types of self-explanation prompts (i.e. prediction prompts and reflection prompts) have any impacts on learning and cognitive load?
(c) What are the relationships among learning, cognitive load, and intrinsic motivation in an interactive multimedia environment?

• Are cognitive load and intrinsic motivation significant predictors of learning outcomes when controlling for learners’ prior knowledge and learning time?
• Does visual cueing moderate the relationships among learning, cognitive load, and intrinsic motivation?

We manipulated two independent variables in the study: cueing (cuing vs. no cueing) and prompting self-explanation (no prompts vs. prediction prompts vs. reflection prompts). The study incorporated a number of dependent variables, including learning outcomes, cognitive load, intrinsic motivation, and learning time.

Method

Participants & design

A total of 126 participants (53 males) were recruited from a large southwestern university in the USA to participate in the study. They were undergraduate students enrolled in an
introductory computer literacy course or an introductory psychology course. They participated in the study to earn credit in their course. They were all over 18 years old with mean age of 21.69 (SD = 5.73). With regard to the ethnicity, 11 of the participants were African Americans, 18 Asians, 71 Caucasians, 18 Hispanics, 2 Native Americans and 6 who belong to other ethnic groups.

This study used a pretest–posttest, 2 (cueing vs. no cueing) × 3 (no prompts vs. prediction prompts vs. reflection prompts) between-subjects design, in which participants were randomly assigned in equal numbers (N = 21) to one of the six conditions:

(a) uncued animations/no prompts,
(b) cued animations/no prompts,
(c) uncued animations/prediction prompts,
(d) cued animations/prediction prompts,
(e) uncued animations/reflection prompts,
(f) cued animations/reflection prompts.

Measures & instruments

A total of 20 multiple choice questions were used as a pretest to measure participants’ existing knowledge about the content – the human cardiovascular system. Each question in the pretest was scored 0 point for the incorrect answer or 1 point for the correct answer by the computer program automatically. The maximum score of the pretest was 20 points. A 20-item posttest was used to measure participants’ learning outcome after instruction. The posttest (Cronbach’s α = .80) had the same format and followed the same scoring procedures as the pretest (Cronbach’s α = .81), but the questions in the pretest and posttest were different. Two sample pretest questions are: (1) “What is a difference between your heart muscle and the muscles in your legs and arms?” and (2) “The right ventricle pumps blood to .” Two sample posttest questions are: (1) “Why does diffusion occur into the blood in the lungs?” and (2) “When blood is sent out from the heart to the body, what part of the heart does it leave?”

We adapted five subjective questions (i.e. task demands, effort, navigational demands, perceived success, and stress, see Table 1) from the NASA-TLX (Hart & Staveland, 1988) to measure learners’ perceived cognitive load. These measures were also described in the previous studies (Gerjets, Scheiter, & Catrambone, 2004, 2006). Each of the questions was administered on an 8-point Likert scale. The Cronbach’s α for these five measures was .75.

We used an 8-point Likert scale to measure participants’ intrinsic motivation. There were a total of six statements (Table 2). These items were adopted from the intrinsic motivation inventory (Deci, Eghrari, Patrick & Leone, 1994; Ryan, 1982). The Cronbach’s α for these measures was .95.

Interactive multimedia environment

The computer-based instructional materials delivered an instructional unit about the human cardiovascular system. Specifically, it covered the following topics: the structure and function of the heart, the blood and blood vessels, the circulatory pathway of blood vessels, and the material exchange in the human body. We used Visual Basic to create the interactive learning environment, which did not impose any time constraints on learners. We also created the 2D graphics with Adobe Flash and embedded them in the learning environment.
Participants could go back and forth within the environment to study the materials from a series of narrated animations. In the uncued animation/no prompts condition (Figure 1), participants viewed 24 screens of presentation, each including one segment of animations and a female narration describing the content; no cues were added to these animations. In the cued animations/no prompts condition (Figure 2), the same number of animation segments were presented to the participants except that each segment of animation was cued using an arrow pointing to the relevant part. The uncued animations/prediction prompts condition was almost identical to the uncued animations/no prompts condition with one exception: four prompting questions were inserted into the computer-based lesson (Table 3). The wording of these prompts was taken from a list of content-free prompts (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001) and rephrased to be content specific. Each of these prediction prompts appeared on a separate screen from the animations. The prompts were presented between Screens 4 and 5, 7 and 8, 13 and 14, and 19 and 20, so that they preceded the presentation of the related instructions. For instance, after participants were presented with the first prediction question “Could you explain the function of blood in your own words?” on the screen, the participants viewed three screens of the uncued animations (Screens 5, 6, and 7) accompanied by narrations explaining the blood’s function in the cardiovascular system. The uncued animations/reflection prompts condition was almost identical to the uncued animations/prediction prompts condition with one exception: the identical four prompting questions appeared after the related
instructions were presented, between Screens 7 and 8, 13 and 14, 19 and 20, and after Screen 24. For instance, after the participants received instruction from the uncued animations from Screens 5, 6, and 7, they were presented with the question “Could you explain

Figure 1. A sample screen of uncued animations.

Figure 2. A sample screen of cued animations.
the function of blood in your own words?” on a separate screen. The cued animations/prediction prompts condition was almost identical to the uncued animations/prediction prompts condition except that an arrow was added to each of the animations in the cued animations/prediction prompts condition. Similarly in the cued animations/reflection prompts condition, all other elements were identical to the uncued animations/reflection prompts condition except that an arrow was added to each segment of the animations, whereas no cueing devices were used in the uncued animations/reflection prompts condition.

**Procedure**
At the beginning of the study the participants needed to sign a consent form for participation. Each participant was seated in front of a computer and was briefed by the experimenter about the procedure of the study. Then the participant interacted with a computer – without time limit – working through the pretest, instruction, the cognitive load, and intrinsic motivation questions, and finally the posttest. After the completion of the pretest, the participant was provided with a randomly assigned experiment ID number to start the computer-based lesson. The purpose of using the experiment ID number was (a) to randomly assign each participant into one of the six experimental conditions and (b) to preserve the anonymity of each participant. Upon completion of the posttest the participants were thanked. It took approximately 35 minutes for a participant to complete the study.

**Results**
Familywise type I error rate was set at .05 level. We used Cohen’s $f$ or Cohen’s $d$ as the effect size index. Accordingly, .10, .25, and .40 are considered as the $f$ values for small, medium, and large effect sizes, and .20, .50, and .80 are considered as the $d$ values for small, medium, and large effect sizes (Cohen, 1988). All learning outcome scores were converted to percentage scores. Descriptive statistics are presented in Table 4.

**Prior knowledge**
We conducted a one-way analysis of variance (ANOVA) to assess whether participants’ prior knowledge differed across the six conditions. The results showed that there was no significant difference, $F(5, 120) = 1.39$, $MSE = 9.11$, $p = .23$, $f = .24$.

**Learning time**
We conducted a two-way ANOVA to evaluate the effects of prompting and cueing on learning time. There were no main effects of prompting or cueing; nor was there an interaction (all $Fs < 1.00$, and all $ps > .30$).

Table 3. Self-explanation prompts.

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Could you explain the function of blood in your own words?</td>
</tr>
<tr>
<td>2. Could you explain how the blood vessels work?</td>
</tr>
<tr>
<td>3. Could you explain pulmonary circulation and systemic circulation</td>
</tr>
<tr>
<td>4. Could you explain the process of material exchange in your own</td>
</tr>
<tr>
<td>words?</td>
</tr>
</tbody>
</table>
Table 4. Descriptive statistics of learning time, learning outcomes, cognitive load, and intrinsic motivation.

<table>
<thead>
<tr>
<th></th>
<th>Cues No cues</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prediction prompts</td>
<td>Reflection prompts</td>
<td>No prompts</td>
<td>Prediction prompts</td>
<td>Reflection prompts</td>
</tr>
<tr>
<td></td>
<td>(N = 21)</td>
<td>(N = 21)</td>
<td>(N = 21)</td>
<td>(N = 21)</td>
<td>(N = 21)</td>
</tr>
<tr>
<td>Learning time(^a)</td>
<td>10.68 (2.62)</td>
<td>10.84 (2.71)</td>
<td>10.51 (1.28)</td>
<td>10.59 (2.62)</td>
<td>10.26 (1.54)</td>
</tr>
<tr>
<td>Pretest</td>
<td>.39 (.12)</td>
<td>.49 (.18)</td>
<td>.42 (.14)</td>
<td>.47 (.12)</td>
<td>.44 (.14)</td>
</tr>
<tr>
<td>Posttest</td>
<td>.73 (.15)</td>
<td>.77 (.03)</td>
<td>.76 (.15)</td>
<td>.73 (.16)</td>
<td>.70 (.03)</td>
</tr>
<tr>
<td>Task demands/CL</td>
<td>5.43 (1.66)</td>
<td>5.05 (1.66)</td>
<td>5.12 (2.38)</td>
<td>4.95 (2.03)</td>
<td>4.78 (2.00)</td>
</tr>
<tr>
<td>Effort/CL</td>
<td>5.05 (1.75)</td>
<td>5.05 (1.75)</td>
<td>4.83 (1.41)</td>
<td>4.78 (1.41)</td>
<td>4.67 (1.41)</td>
</tr>
<tr>
<td>Navigational demands/CL</td>
<td>4.19 (2.40)</td>
<td>3.91 (1.41)</td>
<td>3.95 (1.88)</td>
<td>3.92 (2.00)</td>
<td>3.95 (2.00)</td>
</tr>
<tr>
<td>Perceived success/CL</td>
<td>5.90 (1.41)</td>
<td>6.14 (1.58)</td>
<td>5.92 (1.58)</td>
<td>5.92 (1.77)</td>
<td>5.90 (1.77)</td>
</tr>
<tr>
<td>Stress/CL</td>
<td>2.62 (1.69)</td>
<td>2.41 (1.84)</td>
<td>3.10 (1.84)</td>
<td>3.18 (1.78)</td>
<td>2.86 (1.78)</td>
</tr>
<tr>
<td>IM1</td>
<td>5.95 (1.94)</td>
<td>6.03 (2.44)</td>
<td>5.52 (4.45)</td>
<td>5.42 (2.45)</td>
<td>5.76 (1.95)</td>
</tr>
<tr>
<td>IM2</td>
<td>5.38 (1.75)</td>
<td>5.51 (2.17)</td>
<td>5.02 (1.70)</td>
<td>5.02 (1.70)</td>
<td>5.24 (2.17)</td>
</tr>
<tr>
<td>IM3</td>
<td>6.24 (1.64)</td>
<td>6.33 (1.35)</td>
<td>5.90 (1.70)</td>
<td>5.80 (1.70)</td>
<td>6.48 (1.44)</td>
</tr>
<tr>
<td>IM4</td>
<td>5.24 (2.05)</td>
<td>5.39 (2.43)</td>
<td>4.95 (2.13)</td>
<td>4.83 (2.13)</td>
<td>5.29 (2.43)</td>
</tr>
<tr>
<td>IM5</td>
<td>5.67 (1.62)</td>
<td>5.74 (2.10)</td>
<td>5.29 (2.10)</td>
<td>5.19 (2.10)</td>
<td>5.90 (2.15)</td>
</tr>
<tr>
<td>IM6</td>
<td>5.19 (1.78)</td>
<td>5.33 (2.12)</td>
<td>5.00 (2.12)</td>
<td>4.85 (2.12)</td>
<td>5.05 (1.72)</td>
</tr>
</tbody>
</table>

Note: M, mean; SD, standard deviation; Adj., adjusted; SE, standard Error; CL, cognitive load; and IM, intrinsic motivation.

\(^a\)The unit of time is minute.
Learning outcomes

A two-way analysis of covariance was conducted to evaluate the potential effects of prompting and cueing on the posttest percentage scores. Both learning time and the pretest percentage scores were used as the covariates to control for the potential effects of learning time and prior knowledge. There was a significant main effect of cueing, $F(1, 118) = 12.60$, $MSE = 0.02$, $p = .001$, with a medium-to-large effect size, $f = .33$, power = .96. Participants assigned to the cueing conditions (adjusted mean = .76, standard error = .02) scored significantly higher on the posttest than their peers who were assigned to no-cueing conditions (adjusted mean = .68, standard error = .02), controlling for pretest and learning time. However, the prompting main effect, $F(1, 118) = 1.15$, $p = .32$, $f = .14$, and the prompting-by-cueing interaction, $F(1, 118) = 0.67$, $p = .52$, $f = .11$, were non-significant.

Cognitive load

A two-way multivariate analysis of covariance (MANCOVA) was conducted to determine the potential effects of cueing and prompting on the five cognitive load measures, using the pretest percentage scores and learning time as the covariates. The results showed that neither of the two main effects was significant: for the prompting main effect, Wilks’ lambda = .92, $F(10, 228) = 1.00$, $p = .68$, $f = .20$, and for the cueing main effect, Wilks’ lambda = .98, $F < 1.00$, $p = .84$, $f = .15$. In addition, there was a non-significant interaction: Wilks’ lambda = .94, $F < 1.00$, $p = .84$, $f = .18$.

Intrinsic motivation

We conducted a two-way MANCOVA to determine the effects of prompting and cueing on intrinsic motivation, using the pretest percentage scores and learning time as the covariates. The results showed that neither of the two main effects was significant: for the prompting main effect, Wilks’ lambda = .92, $F < 1.00$, $p = .68$, $f = .20$, and for the cueing main effect, Wilks’ lambda = .98, $F < 1.00$, $p = .84$, $f = .15$. In addition, there was a non-significant interaction: Wilks’ lambda = .94, $F < 1.00$, $p = .84$, $f = .18$.

Relationships among learning, cognitive load, and intrinsic motivation

We conducted structural equation modeling (SEM) analysis with Mplus to evaluate the relationships among the latent variables (learning, cognitive load, and intrinsic motivation) based on a series of observed items (pretest & posttest, cognitive load measures, and intrinsic motivation measures). A hybrid SEM model (Figure 3) was evaluated to explore the relationships among learning, cognitive load, and intrinsic motivation in the interactive multimedia environment. In order to control for the effects of learning time and prior knowledge, two observed variables – learning time and the pretest percentage scores – were included in the model as the control variables. To evaluate the fit of the models, we adopted the criteria of goodness-of-fit indices suggested by Hu and Bentler (1999). Confirmatory factor analyses were conducted to examine the fit of each of the two measurement components—that represents cognitive load and that represents intrinsic motivation. The cognitive load measurement component with five measures had an acceptable fit: $\chi^2(5) = 11.94$, $p = .04$, comparative fit index (CFI) = .95, root mean-square error of approximation (RMSEA) = .06 with 90% confidence interval [.03, .10]. The results also indicated that the intrinsic motivation measurement component had an acceptable model fit: $\chi^2(9) = 14.67$, $p = .11$, CFI = .99, RMSEA = .06 with 90% confidence interval
Finally, we included both measurement components into the hybrid SEM model and evaluated its model fit. The hybrid SEM model showed a good fit, $\chi^2(108) = 140.66, p = .02$, CFI = .97, RMSEA = .05 with 90% confidence interval [.03, .09].

As the participants in the cueing conditions were qualitatively different from their peers in the no-cueing conditions, the hybrid model was separately fitted for the cueing and the no-cueing groups in order to (a) investigate whether cognitive load and intrinsic motivation were significant predictors of learning outcomes and (b) test the potential moderation effect of visual cueing on the relationships among learning outcomes, cognitive load, and intrinsic motivation. In the no-cueing group, the results revealed that cognitive load significantly predicted posttest scores, $z = -2.77, p = .04$, taking into account the two controlling variables, whereas intrinsic motivation did not, $z = -0.54, p = .59$. The correlation between cognitive load and intrinsic motivation within the no-cueing group was small, $r = -.20, p = .13$.

In the cueing group, the pattern reversed; cognitive load was not a significant predictor of posttest scores, $z = -1.65, p = .10$, taking into account the two controlling variables, whereas intrinsic motivation was, $z = 2.21, p = .03$. The correlation between cognitive

---

Table 5. Estimated parameters in the hybrid SEM model.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Unstandardized</th>
<th>Standardized</th>
<th>$z$</th>
<th>$p$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cued group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>-.01</td>
<td>-.14</td>
<td>-1.65</td>
<td>.10</td>
<td>.52</td>
</tr>
<tr>
<td>IM</td>
<td>.02</td>
<td>.23</td>
<td>2.21</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>LT</td>
<td>.01</td>
<td>.22</td>
<td>2.29</td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>.51</td>
<td>.50</td>
<td>4.77</td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td><strong>Uncued group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>-.02</td>
<td>-.19</td>
<td>-2.77</td>
<td>.04</td>
<td>.45</td>
</tr>
<tr>
<td>IM</td>
<td>-.01</td>
<td>-.05</td>
<td>-0.54</td>
<td>.59</td>
<td></td>
</tr>
<tr>
<td>LT</td>
<td>.02</td>
<td>.21</td>
<td>2.25</td>
<td>.13</td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>.75</td>
<td>.66</td>
<td>6.30</td>
<td>.10</td>
<td></td>
</tr>
</tbody>
</table>

Note: CL, cognitive load; IM, intrinsic motivation; LT, learning time; and Pre, pretest score.
load and intrinsic motivation within the cueing group was small, \( r = -0.08, p = .56 \). In summary, while controlling for prior knowledge and learning time, cognitive load and intrinsic motivation had different impacts on learning outcomes in the multimedia environment due to the moderation effect of cueing. Parameter estimates are presented in Table 5.

Discussion and conclusion

The purpose of the current study was to investigate the impacts of visual cues and different types of self-explanation prompts on learning, cognitive load, and intrinsic motivation in an interactive multimedia environment that delivered instruction about the human cardiovascular system. The results of the study revealed two major findings: (a) participants presented with cued animations had significantly higher learning outcome scores than their peers who viewed uncued animations and (b) while controlling for prior knowledge and learning time, cognitive load and intrinsic motivation had different impacts on learning outcomes in the interactive multimedia environment due to the moderation effect of cueing. These results are discussed below.

Is cueing effective in positively influencing cognitive load and enhancing learning outcomes? The results of the current study revealed that cueing by using an arrow enhanced learning about the human cardiovascular system. This beneficial effect of cueing is consistent with a number of empirical studies in the current literature (Kalyuga et al., 1999; de Koning et al., 2007, 2010c), which advocate the utilization of visual cues in the interactive multimedia environments. Whereas the current study and the two studies by de Koning et al. (2007, 2010c) revealed the benefits of cueing in learning about the human cardiovascular system, our study extended this effect by showing that learning can be enhanced not only by spotlight cueing, but also by arrow cueing. It is of note that Boucheix and Lowe (2010) found that arrow-cueing devices, which are separate entities on the animations, were not as effective as color-cueing devices, which are embedded within the animations. However, multiple arrow cues were added to the animations in Boucheix and Lowe’s study. A possible consequence is that learners did not know where they should pay special attention when they were presented with too many cueing devices. In contrast, the current study utilized a single-arrow cue to direct learners’ attention to the thematically important information. Thus, the conclusion, based on previous studies, that arrow cueing is ineffective may be not very convincing. The unique contribution of this study, which revealed a medium-to-large cueing effect, is that the single-arrow cue is effective in terms of learning. Learners may be able to focus their attention more easily on the portion of the visualization to which the arrow pointed. The implication for instructional design is that visual cues in the form of arrows have the potential to enhance learning if instructional designers and developers apply this type of cueing device sparingly and apply it to important visualizations.

Our results did not show that cueing had any impacts on cognitive load, although we found a positive cueing effect on learning. One possibility, as suggested by Lowe and Boucheix (2011), is that the cueing effect to direct attention and reduce visual search may disappear after learners are presented with a series of cued animations. If this proposition is true, that would explain why there was no significant difference in cognitive load measures. One limitation of the current study is that we were unable to examine visual search and cognitive load during instruction, especially in the initial stage of the instruction. Therefore, future research is needed to clarify this ambiguity.

Do different types of self-explanation prompts (i.e. prediction prompts and reflection prompts) have any impacts on learning and cognitive load? The results did not reveal
any benefits of self-explanation prompts, regardless of whether they were administered right before the delivery of the related instruction to prompt learners to predict what was to be learned or right after the related instruction to let learners reflect on what they had learned. Similarly, some empirical studies also revealed non-significant results with self-explanation prompts (Große & Renkl, 2006; de Koning, et al., 2010c; Moreno & Mayer, 2005). Gerjets et al. (2006) even found a small preventative prompting effect on learning. One possibility is that participants’ self-explanation process, which was prompted by those questions, was demanding and effortful. This situation may lead participants to study without doing any self-explanation in the interactive environment where they were provided with full learner control. Therefore, the data we collected cannot reflect the effect of prompting, regardless of whether cueing was accompanied or not. In contrast to our results, de Koning, Tabbers, Rikers, and Paas (2010b) revealed that cued animations can be optimized by generating self-explanation. In that study, the experimenter orally prompted learners to elicit self-explanation, which suggests future research investigate the effect of self-explanation prompts implemented by a human or a computer in the interactive multimedia environment in which visual cues are utilized.

What are the relationships among learning, cognitive load, and intrinsic motivation in an interactive multimedia environment? Although researchers proposed various theoretical models related to motivation in multimedia learning, the literature rarely provided evidence to support these theories. Therefore, the relationships among learning, cognitive load, and intrinsic motivation in the interactive multimedia environment are still unknown. The current study addressed this issue by investigating whether cognitive load and intrinsic motivation predicted learning when prior knowledge and learning time were controlled and whether cueing moderated such relationships. The results showed that cueing was a moderator. In the no-cueing conditions, cognitive load negatively predicted learning, whereas in the cueing conditions intrinsic motivation positively predicted learning. These results suggest that when no cueing was applied, extraneous load may have been heightened, which may have increased the amount of overall load and consequently prevent learning. In contrast, when cueing devices were applied, extraneous load may have been reduced, which may have intrinsically motivated learners to pursue learning. One of the limitations of this interpretation is that we cannot know the fluctuation of a specific type of cognitive load within this framework based on only five cognitive load measures as we need to take into account the practical issue of SEM (i.e. whether the SEM model can be identified). As cognitive load research advances, researchers will provide more instruments for measuring cognitive load, which may help us further investigate how a specific type of cognitive load influences learning and intrinsic motivation.

The results that showed cueing’s moderation effect also imply that cueing may impact learning, cognitive load, and intrinsic motivation in an indirect way, even though cueing’s direct impacts on cognitive load and intrinsic motivation are not obvious (i.e. statistically non-significant). It is of note that cognitive load was not substantially correlated with intrinsic motivation in this study, which implies that cognitive load and intrinsic motivation have different and unique impacts on learning. Related to this result are two arguments: (a) motivation and cognitive load overlap (Rey & Buchwald, 2011; Schnitz, Fries, & Horz, 2009) and (b) motivation mediates learning (according to CATLM, cf. Moreno, 2009; Moreno & Mayer, 2007). What we can add to the first argument is that motivation and cognitive load indeed overlap, but not substantially. With regard to the second argument, the small-sized correlation revealed in our study implies that mediation effects are not applicable (Baron & Kenny, 1986).
These results, which show our endeavors to explore the impacts of two instructional aids on learning, cognitive load, and intrinsic motivation, imply that attempts to include motivation as a modification to CLT and CTML need to take into account the context of different instructional designs and manipulations in the interactive environment. These theoretical modifications need further empirical interrogation. Empirically, both motivation and cognitive load measures should be considered in the research related to cognitive load and multimedia learning, as motivation and cognitive load contribute differently to learning under different instructional conditions. For educational practice, we recommend that the design and development of interactive learning environments need to consider both learners’ cognitive processes and their motivation.

Acknowledgments
This research was partially supported by “Chen Guang” Project (12CG27) of Shanghai Municipal Education Commission and Shanghai Education Development Foundation, Shanghai Pujiang Program (13PJC031), and the Scientific Research Foundation for the Returned Overseas Chinese Scholars, State Education Ministry, China.

Notes on contributors
Lijia Lin, Ph.D., is an assistant professor in the School of Psychology and Cognitive Science at East China Normal University in Shanghai, China.

Robert K. Atkinson, Ph.D., is an associate professor in the School of Computing, Informatics, and Decision Systems Engineering at Arizona State University in the USA.

Wilhelmina C. Savenye, Ph.D., is a professor in Mary Lou Fulton Teachers College at Arizona State University in the USA.

Brian C. Nelson, Ed.D., is an associate professor in the School of Computing, Informatics, and Decision Systems Engineering at Arizona State University in the USA.

References


