Yang, H. Y. (2016). The Effects of Attention Cueing on Visualizers' Multimedia Learning. *Educational Technology & Society, 19* (1), 249–262.

The Effects of Attention Cueing on Visualizers' Multimedia Learning

Hui-Yu Yang
Foreign Language Department, Fujian University of Technology, Fujian, China // yangh936@163.com

(Submitted October 30, 2014; Revised April 5, 2015; Accepted May 23, 2015)

ABSTRACT

The present study examines how various types of attention cueing and cognitive preference affect learners' comprehension of a cardiovascular system and cognitive load. EFL learners were randomly assigned to one of four conditions: non-signal, static-blood-signal, static-blood-static-arrow-signal, and animation-signal. The results indicated that attention cueing yielded similar performance but helped reduce the learners' mental load. No interaction effects between cognitive style and the experimental conditions on the learners' total score and cognitive load were observed. Both high- and low-visualizers benefited equally well from attention cueing. However, an interaction effect in one subtest was observed indicating that attention cueing can result in learning interference among high-visualizers. Contrary to the hypothesis, the presence of attention cueing did not optimize conceptual understanding.

Keywords

Animation, Dual coding, Cognitive preference, Cognitive load, Signaling principle

Introduction

Without proper guidance, learners' attention might become distracted when learning an unfamiliar subject in a multimedia environment. The presence of visual cues is assumed to direct learners' attention to the most essential elements, help organize that information into a coherent structure, and optimize conceptual understanding (Mayer, 2009). According to the signaling principle, attention cueing is predicted to reduce learners' extraneous load (Mayer & Moreno, 2010) and promote learning.

In addition, dual coding theory (Paivio, 1986) assumes that the human cognitive system has two independent but interconnected verbal and non-verbal mental systems. Active mental representation activates relevant nodes in the network, and the spreading activation triggers a wide range of associated verbal and imagery representations in the network. Past experiences and individual differences determine the quantity and quality of activation (Clark & Paivio, 1991). Learners' cognitive preference (Hegarty, Kriz, & Cate, 2003; Plass, Chun, Mayer, & Leutner, 1998) and prior knowledge (Imhof et al., 2013) are predicted to moderate learning efficiency. Visualizers have been found to benefit from multimedia (e.g., Chen, Hsieh, & Kinshuk, 2008; Plass et al., 1998) due to their strong visuospatial capabilities in constructing mental models.

This study expands upon previous research conducted on the effects of attention cueing in multimedia learning with the aim of addressing the questions of whether or not attention cueing can reduce learners' cognitive load and the ways in which different types of cognitive styles and attention cueing affect learning efficiency.

Literature review

Cognitive load theory

The information processing that occurs in working memory involves: (1) selection of relevant words, (2) selection of relevant images, (3) organization of selected words, (4) organization of selected images, and (5) integration of visual and auditory information with prior knowledge (Mayer, 2009). During information processing, three types of cognitive load may affect learning efficiency: extraneous, intrinsic, and germane. Extraneous cognitive load is caused by poor instructional design (Moreno & Mayer, 2010) but may be minimized by providing attention cueing (Mayer, 2009). Due to limited working memory capacity, the presence of attention cueing is predicted to direct learners' attention to the target, thus minimizing the visual search process, releasing more cognitive resources with which learners can engage in schema construction and activation, and facilitate the germane load (de Koning, Tabbers, Rikers, & Paas, 2009), which is beneficial for learning.

Signaling principle

In terms of cognitive processing, attention cueing is classified into selection, organization, and integration cues – corresponding with the cognitive abilities of selecting, organizing, and integrating information in the working memory. Selection cues guide learners' attention to the most essential elements in the representations (Crooks, Cheon, Inan, Ari, & Flores, 2012; de Koning et al., 2008, 2009). Organization cues assist learners in organizing the elements of the representations to better facilitate text processing and improve retention (Crooks et al., 2012; de Koning et al., 2008, 2009), such as number signals showing steps in causal chains to build up internal connections among causal elements (Harp & Mayer, 1998). Integration cues aid the learners in integrating the elements between and within the representations into a coherent whole (de Koning et al., 2009). In terms of perceptual processing, unique colors or moving objects seem to be effective in capturing learners' attention. Two features that influence perceptibility of visual representations include visual contrast (i.e., an element with distinctive features stands out from the background) and dynamic contrast (i.e., movement or temporal changes in an element demonstrate figure-ground differences) which seem to direct learners' attention to the target and reduce their extraneous cognitive load (de Koning et al., 2009).

Relevant studies about attention cueing in multimedia learning

Crooks et al. (2012) examined the effects of cueing and modality on a self-paced computer-based diagram depicting places of articulation in human speech. The learners were presented with either written or spoken text with the presence or absence of arrow and color cueing. No significant effects of cueing on learning efficiency and mental loads were observed. Lin and Atkinson (2011) investigated the efficiency of visual cueing in either animation or static graphics on learning rock cycles. Learners in both the visual and non-visual cueing conditions performed equally well and experienced similar cognitive load.

In a study conducted by Tabbers, Martens, and van Merriënboer (2004), they found that providing cues enhanced learning efficiency but yielded similar cognitive loads under all conditions. Imhof et al. (2013) also explored the effects of arrow cueing on learning fish locomotion patterns. The learning conditions included: (a) multiple visualizations without arrows, (b) multiple visualizations with arrows, and (c) single visualization with arrows. The first and third conditions were beneficial in facilitating learning efficiency by comparing multiple pictures or making dynamic information explicit. The second condition appeared to cause interference and hinder learning. The ineffectiveness of cueing on animation might be due to interference caused by the simultaneous highlighting of multiple elements without specificity (Moreno, 2007).

Similarly, Kriz and Hegarty (2007) conducted a study probing the effects of arrow cueing on learning a flushing cistern. The learners who received arrow cues did not significantly outperform those who did not receive arrow cues in comprehension and troubleshooting tests. The authors suggest that presenting attention cueing may help learners focus their attention only on the most relevant elements, but without ensuring effective conceptual understanding and mental model constructions of the visual representations.

Additional activities (i.e., display speed, self- or instructional explanations) accompanied with cues may help learners engage in deep learning (de Koning et al., 2009). de Koning and his colleagues conducted a number of studies by decreasing the luminance of uncued subsystems to show their visual contrast with cued subsystems in an animated cardiovascular system. In one study concerning presentation speed (de Koning et al., 2011a), the learners exhibited similar performance results on retention and transfer tests regardless of cueing conditions and display speeds. It was also found that low-speed group experienced a higher cognitive load than did those in high-speed conditions. This was probably due to the fact that in the low-speed condition, learners had to integrate and keep the information active in their working memory for a longer period of time which generated a greater extraneous load as compared with the learners in the high-speed conditions. In addition, the other two studies addressing the self- or instructional explanations accompanied with attention cueing (de Koning et al., 2010b, 2011b) yielded mixed results. Self- or instructional explanations accompanied by visual cueing seemed to optimize the learners' conceptual understanding of the causal relations of animated cardiovascular system, yielded better performance, and reduced cognitive load. However, in terms of efficiency, the effect of self- or instructional explanations was unclear. On the other hand, in their other studies, they found positive effects of attention cueing on learning efficiency as demonstrated by learners' performances on transfer and inference tasks (de Koning et al., 2008, 2010b, 2011b).

Kalyuga, Chandler, and Sweller (1999) compared the effects of conventional separate-diagram-and-text and color-coded-diagram-and-text situations on learning an electrical circuit. The conventional group was given an electrical circuit with a written text underneath, whereas the color-coded-diagram-and-text group was presented with the same diagram and text but with additional color cueing on the electrical elements in which unique coloring schemes appeared when the learners clicked on the text. Those in the color-cueing group showed better test performance and lower cognitive load than did those in the conventional group. When dealing with split-attention diagrams where the text and diagrams are presented simultaneously, the text should be marked with color-cueing that draws the learners' attention.

In sum, studies investigating the supposed benefits of visual attention cueing on multimedia learning efficiency have yielded mixed results. Administering attention cueing may facilitate learning efficiency (e.g., Amadieu et al., 2011; Boucheix et al., 2011; de Koning et al., 2010b, 2011b; de Koning & Tabbers, 2013; Imhof et al., 2013; Kalyuga et al., 1999) and reduce learners' extraneous cognitive load (e.g., Amadieu et al., 2011; Kalyuga et al., 1999); or it may facilitate learning efficiency without reducing cognitive load (de Koning et al., 2008, 2010b; Tabbers et al., 2004); or it might be ineffective (e.g., Crooks et al., 2012; de Koning et al., 2010a, 2011a; Kriz & Hegarty, 2007; Lin & Atkinson, 2011; Moreno, 2007) and even causes interference (e.g., Imhof et al., 2013; Moreno, 2007).

Cognitive preference: Visualizers vs. verbalizers

Learners' cognitive styles have also been thought to affect learning efficiency. However, previous studies investigating this theoretical assumption also showed inconsistent results. Studies conducted by Chen et al. (2008), Leutner and Plass (1998), and Plass et al. (1998) have indicated that visual representations benefit visualizers more due to their strong visuospatial capabilities in constructing mental models. However, Hegarty et al. (2003), Imhof et al. (2013), Jones (2009), and Plass et al. (2003) have found that visual representations may not support cognitive preferences. On the other hand, Höffler (2010) has even suggested that multimedia can compensate for verbalizers' low-visuospatial capabilities and thus benefit them more.

Hegarty et al. (2003) conducted three experiments investigating learners' mental animation ability on learning the mechanism in a flushing cistern. They found that providing learners with verbal text may be sufficient to help them construct mental imagery, while animation may not be superior to static diagrams in enhancing learners' retention and troubleshooting abilities. Specifically, the high visual learners outperformed the low visual learners in all conditions but did not display significant interaction effects with the experimental treatments.

Statement of the problem

The issue over whether providing attention cueing enhances learning efficiency (e.g., Boucheix et al., 2011; de Koning et al., 2008, 2010b, 2011b; de Koning & Tabbers, 2013; Kalyuga et al., 1999) or fails to optimize learning (e.g., Crooks et al., 2012; de Koning et al., 2010a, 2011a; Harp & Mayer, 1998; Lin & Atkinson, 2011) remains controversial. Besides, previous studies used diagrams/animation alone, but the presentation of visual imagery without verbal explanations may be insufficient for learners to understand abstract concepts. Verbal texts that accompany diagrams/animation may vividly illustrate abstract concepts and benefit learners (Kriz & Hegarty, 2007). Finally, the ability to construct mental imagery is related to one's visuospatial capabilities (Hegarty et al., 2003); however, whether high visual learners benefit from visual representations with attention cueing is under question. To address the unresolved questions, the research questions in the present study are as follows:

- Do learners perform differently on dependent measures in different learning conditions?
- Do learners in different conditions experience different cognitive loads?
- Do cognitive preference and experimental treatment affect learners' performance and cognitive load?

Methodology

Participants

The participants were comprised of 169 undergraduates (male = 31, female = 138) with an average age of 19 (M = 19.30, SD = 0.91) enrolled in a foreign language department at a science and technology university in southeastern China. None of them had the background of biology, nor were they familiar with the material in the present study.

Prior knowledge level

A prior knowledge questionnaire with four statements was first administered to assess participants' background (de Koning et al., 2008, 2011b). The learners self-rated their understanding of blood circulation by marking on a nine-point scale measuring their responses to the statements such as "My understanding of a cardiovascular system is…" and "My interest in reading books and magazines about medical science is…." A one-way ANOVA revealed no significant differences among the four groups, $F(3,166) = 0.51$, $p > 0.05$.

Variables

The experimental treatment and cognitive style were manipulated as between-subjects variables. Retention, pictorial recall, matching, and identification tests, and cognitive load were measured as dependent variables (Figure 1).

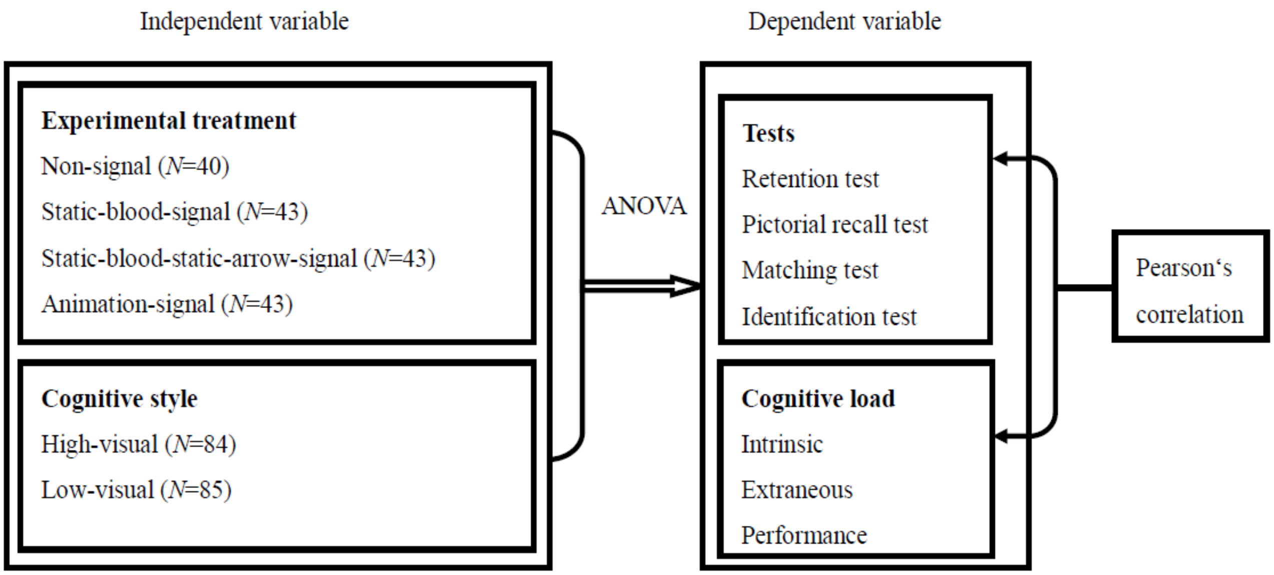

Figure 1. Experimental design

Independent variables

Cognitive style measurement

The learners' cognitive styles were identified using the index of learning styles questionnaire, developed by Felder and Soloman (1997). The questionnaire comprised 44 alternative-choice questions. Learners with a rating at or above index 5 on the visual scale were classified as high-visualizers. Those with a rating at index 1 on the visual scale were classified as low-visualizers. A one-way ANOVA revealed no significant differences among the four groups, $F(3,166) = 1.196$, $p > 0.05$.

Experimental treatment

The cues provided included selection, organization, and integration cues. The selection cues (i.e., the presence of blood guided learners' attention to the target) were used in three experimental conditions, and they were assumed to reduce the learners' perceptual load (Crooks et al., 2012; de Koning et al., 2009). Organization cues (i.e., the presence of number heading in three picture slides indicating steps of a heartbeat cycle) (de Koning et al., 2009; Harp & Mayer, 1998) were used in all experimental conditions. Integration cues (i.e., the presence of blood and arrows which helped learners connect related elements between and within the visual representations and explicated causal and temporal relations) were used in experimental conditions two and three, and they were assumed to help reduce the learners' perceptual and cognitive loads (Crooks et al., 2012; de Koning et al., 2009).

Dependent variables

Retention test

The retention test, comprised of thirteen multiple-choice questions, was designed to assess how well the learners understood the instrumentation. Item 8 dealt with the structure of the heart; items 3, 4, and 11 were related to heartbeats; items 2, 9, and 10 focused on the functions of valves; items 1, 5, and 6 focused on contractions; and items 7, 12, and 13 dealt with blood circulation.

Pictorial recall test

The pictorial recall test, comprised of ten static pictures, was aimed at examining the learners' comprehension of the instrumentation. Each multiple-choice question was comprised of one picture with four answer choices. Items 2, 9, and 10 dealt with the contraction of ventricles; items 1, 4, 5, and 6 were concerned with how blood returns from the body and collects in the atria; items 3, 7, and 8 dealt with the contraction of the atria.

Matching test

One static diagram concerning long and short loops was used to examine whether the learners could apply what they learned and indicate where blood flows in the human body. There were twelve labels in general terms rather than technical terminology (de Koning et al., 2011b) that needed to be matched with corresponding parts in the diagram. Items 1-4 dealt with the structure of the heart; items 5-8 were related to body parts; and items 9-12 dealt with how and where blood exchanges oxygen in the human body.

Identification test

One static diagram regarding long and short loops was to examine whether the learners could apply what they learned and mark the correct steps in the circulatory system on the diagram. There were ten blanks that needed to be filled in to show the steps in the blood circulation process.

Cognitive load measurement

A subjective cognitive load measurement with a scale ranging from 1 to 9 (Kalyuga, Chandler, & Sweller, 1999; Paas, 1992) measured learners' cognitive load. Item 1-3 dealt with intrinsic load; items 4-6 probed extraneous load; and items 7-10 dealt with performance load.

Instrumentation

The texts and pictures were adopted from *Knowledge—Encyclopedia*, published by Dorling Kindersley, Inc., (2013). The text (335 words) and pictures (concerning heartbeat cycles) were made into PowerPoint slides. The instructional materials included: (1) blood circulation, (2) heartbeats, (3) structure of the heart, (4) function of valves, and (5) heartbeat cycle. A time counter was above each slide to control presentation time, and each slide was presented only once for 40 seconds. The overall presentation lasted for six minutes.

In the fifth section, the written text was accompanied by three pictures illustrating: (1) filling up the atria; (2) contraction of the atria; and (3) contraction of the ventricles. The remaining sections contained written text only without pictorial illustrations.

Except for the introduction slide, the instructional materials comprised an average of about 35 words on each slide. In the fifth section, three pictures depicted each of the three steps involved in how blood circulates in and out of the heart. All the control and experimental groups were shown these three pictures in section five of the instrumentation. For the non-signal group (NSG), the slides contained written text plus static pictures without blood and arrow cues (Figure 2a). In the static-blood-signal group (SBG), the slides contained written text plus static pictures along with static blood cues embedded in the illustrations (Figure 2b). In the static-blood-static-arrow-signal group (SBSAG), the slides contained written text and static pictures embedded with static blood and arrow cues indicating the path and direction of blood flows (Figure 2c). In the animation-signal group (ASG), the slides contained written text with static pictures, but with animated blood and arrow cues indicating the movement path and direction of blood flow (Figure 2d). In the ASG, the animated arrows and blood were triggered by clicking the mouse and appeared gradually on the static diagrams to indicate how blood flows in and out of the heart. When the animation feature was in a resting state, the number and position of animated arrows and blood in the diagrams were the same as those in the SBSAG, except that the animation in the ASG was played three times to help learners capture the transiency of the animation.

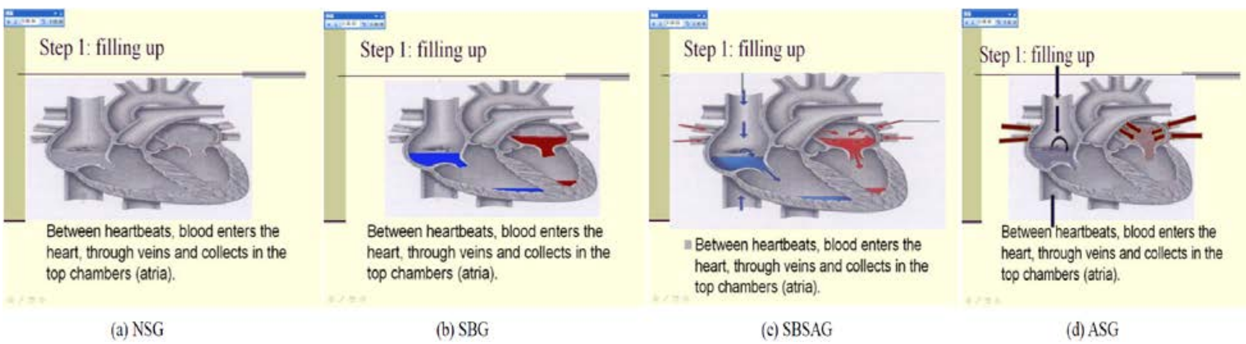

Figure 2. Sample screenshots in the control and experimental conditions

Experimental procedures

The experiment was conducted during the students' regular class period in a language laboratory containing 60 student seats and a computerized teacher control system from which the teacher could control the computer system and monitor all the students. The researcher sat at the computer system to control the presentation, as well as turn on/off the computer monitors.

First, the researcher gave students instructions regarding: (1) how to answer prior knowledge questionnaire, (2) how to answer the cognitive style measurement, (3) how to participate in activities pertaining to a cardiovascular system, (4) how to answer the retention, pictorial recall, matching, and identification tests, (5) what they were not allowed to do during the tests, and (6) how to complete the cognitive load questionnaire.

Prior to conducting the experiment itself, the students first filled out the prior knowledge questionnaire. Secondly, they completed the index of learning style questionnaire. Thirdly, they received 11 preview questions (one stem with four alternatives) presented on each student's computer monitor as advance organizers to activate their prior knowledge (Herron et al., 1998). The preview questions presented in mandarin Chinese provided no clues for answering the forthcoming comprehension tests (Herron, 1994). Fourthly, they received the instrumentation. Fifthly, they received the retention, pictorial recall, matching, and identification tests sequentially on each student's computer monitor at their seat. The students needed to respond by writing down their answer choices on an answer sheet. They were not permitted to return to previous questions (de Koning et al., 2011b) to reduce the possibility of making inferences from them. They were also not allowed to return to previously-presented instructional materials, talk to their peers, or use a dictionary while taking the tests. However, they were permitted to complete the tests at their own rate. Finally, they completed a self-rated cognitive load questionnaire. After completing the tests and questionnaires, they handed in their answer sheets and left the laboratory. The data from the control and experimental groups were collected in separate class periods.

Data collection instruments

A pilot study involving 51 English majors was conducted prior to the experiment. Point-biserial correlation was conducted to examine the reliability of each measurement.

Self-rated prior knowledge scale (Cronbach's alpha = 0.831)

Following item analyses, all items were preserved.

Retention test (Cronbach's alpha = 0.77)

The students had to choose the best answer among the four alternatives in each question (Figure 3a). Each correct answer was worth one point. Following item analyses, two items (i.e., items 6 & 8) were removed and eleven items were retained.

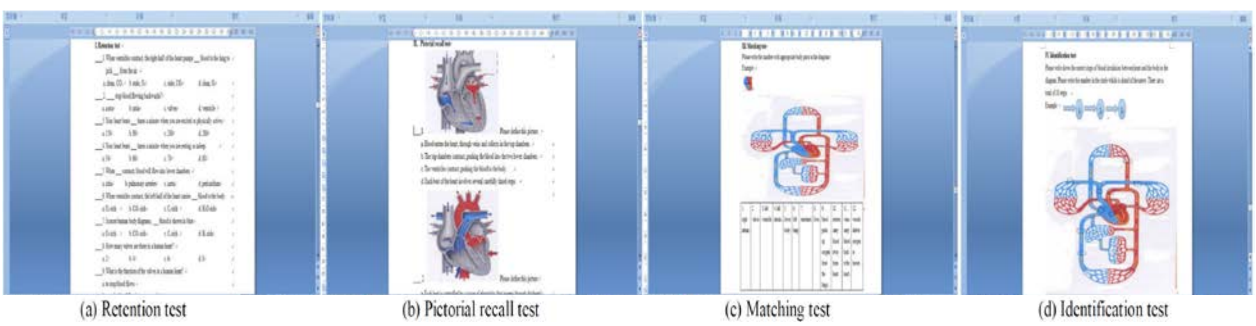

Figure 3. Sample screenshots of the four subtests

Pictorial recall test (Cronbach's alpha = 0.791)

The students had to choose the best answer among the four alternatives to describe the picture (Figure 3b). Each correct answer was worth one point. Following item analyses, three items (i.e., items 1, 3, & 6) were removed and seven items were retained.

Matching test (Cronbach's alpha = 0.788)

The students were required to match each label with a corresponding body part in the diagram (Figure 3c). Each correct mark was worth one point and each ambiguous mark received no point. All items were preserved.

Identification test (Cronbach's alpha = 0.955)

The learners had to mark the steps from 1 to 10 on the diagram (Figure 3d). Each correct mark was worth one point and ambiguous marks (i.e., random steps, scribble, etc.) received no points. All items were preserved.

All four subtests

Cronbach's alpha of all 40 test items was 0.869 indicating that the measurement was highly reliable (Wu & Tu, 2006).

Cognitive style measurement (Cronbach alpha = 0.89)

Only the visual and verbal scales in the index of learning styles questionnaire were considered. The strength of the style was indicated by an index ranging from 1 to 11 with 1 representing the lowest level and 11 representing the highest level.

Cognitive load measurement (Cronbach's alpha = 0.864)

Bartlett's test of sphericity was significant and Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was 0.866. The eigenvalue was greater than 1. The total explained variance was 56.876%, implying that the construct validity of the rating scale was good.

Results

Research question one: Do learners perform differently on dependent measures in different learning conditions?

The results of the one-way ANOVA indicated no significant differences among the four groups on the retention test, $F(3,166) = 0.552$, $p = 0.648$; the pictorial recall test, $F(3,166) = 2.095$, $p = 0.103$; the matching test, $F(3,166) = 1.512$, $p = 0.213$; the identification test, $F(3,166) = 0.135$, $p = 0.939$; and the total score, $F(3,166) = 0.859$, $p = 0.464$. The learners in the experimental groups did not outperform their counterparts in the control group (Table 1).

Table 1. Results of one-way ANOVA for tests

Test		Sum of squares	*df*	*MS*	*F*	*Sig.*
Retention	Between groups	8.108	3	2.703	.552	.648
	Within groups	813.239	166	4.899		
Pictorial recall	Between groups	26.400	3	8.800	2.095	.103
	Within groups	697.253	166	4.200		
Matching	Between groups	28.292	3	9.431	1.512	.213
	Within groups	1035.614	166	6.239		
Identification	Between groups	7.128	3	2.376	.135	.939
	Within groups	2919.225	166	17.586		
Total score	Between groups	143.774	3	47.925	.859	.464
	Within groups	9260.720	166	55.787		

Research question two: Do learners in different conditions experience different cognitive loads?

A one-way ANOVA using Tukey HSD test was used to compare the differences among the four groups in terms of intrinsic, extraneous, performance and overall cognitive loads (Table 2). There was a significant difference regarding intrinsic load, $F(3,166) = 2.501$, $p = 0.045$. Those in the NSG ($M = 19.93$, $SD = 3.62$) had higher intrinsic load than did those in the ASG (*M* = 17.05, *SD* = 4.89), *p* = 0.042. There was no significant difference concerning extraneous load, *F*(3,166) = 1.611, *p* = 0.189. There was a significant difference in performance load, *F*(3,166) = 4.185, *p* = 0.007. Those in the NSG (*M* = 28.05, *SD* = 4.93) had significantly higher performance load than did those in the SBG (*M* = 23.47, *SD* = 8.11), *p* = 0.012; SBSAG (*M* = 23.91, *SD* = 7.24), *p* = 0.036; and ASG (*M* = 23.81, *SD* = 5.99), *p* = 0.023. There was also a significant difference in overall cognitive load, *F*(3,166) = 2.90, *p* = 0.037. Those in the NSG (*M* = 71.75, *SD* = 10.46) had significantly higher overall cognitive load than did those in the ASG (*M* = 62.81, *SD* = 14.35), *p* = 0.042.

Table 2. Results of one-way ANOVA on cognitive load

Load	Group	*M*	*SD*		Sum of squares	*df*	*MS*	*F*	*Sig.*
Intrinsic	NSG	19.93	3.62	Between groups	181.456	3	60.485	2.501	.045*
	SBG	18.65	5.84	Within groups	4014.449	166	24.183		
	SBSAG	17.84	4.92						
	ASG	17.05	4.89						
Extraneous	NSG	16.90	3.49	Between groups	82.740	3	27.580	1.611	.189
	SBG	14.91	4.70	Within groups	2842.583	166	17.124		
	SBSAG	15.65	4.13						
	ASG	15.91	4.07						
Performance	NSG	28.05	4.93	Between groups	564.472	3	188.157	4.185	.007**
	SBG	23.47	8.11	Within groups	7463.905	166	44.963		
	SBSAG	23.91	7.24						
	ASG	23.81	5.99						
Total loads	NSG	71.75	10.46	Between groups	2027.272	3	675.757	2.900	.037*
	SBG	64.23	19.00	Within Groups	38681.322	166	233.020		
	SBSAG	63.58	15.52						
	ASG	62.81	14.35						

Note. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Research question three: Do cognitive preference and experimental treatment affect learners' performance and cognitive load?

A Pearson correlation revealed a statistically significant negative correlation between total score and cognitive load, *r* = -0.202, *p* = 0.008. As learners' cognitive load decreased, their test performances increased, and vice versa.

A two-way ANOVA using Tukey as a post hoc test was conducted to examine the interactive effects between the experimental conditions and cognitive style on the four subtests and total score (Table 3). The ANOVA source of variation results indicated no interaction effects on the retention test, *F*(3,161) = 1.174, *p* = 0.321, partial η^2 = 0.021; on the pictorial recall test, *F*(3,161) = 0.352, *p* = 0.788, partial η^2 = 0.007; or on the matching test, *F*(3,161) = 0.161, *p* = 0.923, partial η^2 = 0.003. However, interaction effects were found on the identification test, *F*(3,161) = 2.887, *p* = 0.037, partial η^2 = 0.051. The one-way ANOVA and the follow-up contrasts comparing both high- and low-visualizers in the four conditions showed that the high-visualizers in the NSG (*M* = 6.00, *SD* = 4.03) significantly outperformed the high-visualizers in the ASG (*M* = 3.25, *SD* = 3.88), *t*(80) = 2.207, *p* = 0.030 (Table 4). However, the low-visualizers in the ASG (*M* = 5.79, *SD* = 4.26) had higher score than the low-visualizers in the NSG (*M* = 3.81, *SD* = 4.18), SBG (*M* = 3.70, *SD* = 4.34), and SBSAG (*M* = 3.68, *SD* = 3.88), but did not reach the significance level, *p* > 0.05. There were no interaction effects overall, *F*(3,161) = 1.033, *p* = 0.380, partial η^2 = 0.019.

Table 3. Results of two-way ANOVA on tests

Source	Test	Type III sum of squares	*df*	*MS*	*F*	*Sig.*	η^2_p
Group	Retention	9.308	3	3.103	.632	.595	.012
	Pictorial	25.605	3	8.535	2.018	.114	.036
	Matching	29.493	3	9.831	1.538	.207	.028
	Identification	6.557	3	2.186	.129	.943	.002
	Total	139.956	3	46.652	.837	.475	.015

Style	Retention	5.784	1	5.784	1.179	.279	.007
	Pictorial	11.167	1	11.167	2.640	.106	.016
	Matching	1.981	1	1.981	.310	.578	.002
	Identification	17.864	1	17.864	1.055	.306	.007
	Total	73.375	1	73.375	1.317	.253	.008
Group * Style	Retention	17.279	3	5.760	1.174	.321	.021
	Pictorial	4.470	3	1.490	.352	.788	.007
	Matching	3.080	3	1.027	.161	.923	.003
	Identification	146.622	3	48.874	2.887	.037*	.051
	Total	172.641	3	57.547	1.033	.380	.019
Error	Retention		161	4.906			
	Pictorial		161	4.230			
	Matching		161	6.392			
	Identification		161	16.930			
	Total		161	55.715			

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 4. Contrast test of the identification test results

Group	Visual	*M*	*SD*	Contrast test of high-visualizers	Value of contrast	Std. error	*t*	*df*	*Sig.* (2-tailed)
NSG	High	6.00	4.03	NSG vs. SBG	.95	1.300	.731	80	.467
	Low	3.81	4.18	SBSAG vs. ASG	2.04	1.213	1.679	80	.097
SBG	High	5.05	3.73	SBG vs. SBSAG	-.24	1.268	-.186	80	.853
	Low	3.70	4.34	NSG vs. ASG	2.75	1.246	2.207	80	.030*
SBSAG	High	5.29	4.55	SBG vs. ASG	1.80	1.229	1.465	80	.147
	Low	3.68	3.88						
ASG	High	3.25	3.88						
	Low	5.79	4.26						

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 5. Results of two-way ANOVA on cognitive load

Source	Load	Type III sum of squares	*df*	*MS*	*F*	*Sig.*	η^2_p
Group	Intrinsic	194.926	3	64.975	2.686	.048*	.048
	Extraneous	87.826	3	29.275	1.695	.170	.031
	Perform	591.611	3	197.204	4.336	.006**	.075
	Total	2183.619	3	727.873	3.103	.028*	.055
Style	Intrinsic	14.310	1	14.310	.591	.443	.004
	Extraneous	17.982	1	17.982	1.041	.309	.006
	Perform	76.008	1	76.008	1.671	.198	.010
	Total	72.457	1	72.457	.309	.579	.002
Group * Style	Intrinsic	55.665	3	18.555	.767	.514	.014
	Extraneous	15.808	3	5.269	.305	.822	.006
	Perform	17.687	3	5.896	.130	.942	.002
	Total	352.702	3	117.567	.501	.682	.009
Error	Intrinsic		161	24.194			
	Extraneous		161	17.271			
	Perform		161	45.478			
	Total		161	234.594			

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Another two-way ANOVA using Tukey as a post hoc test was conducted to examine the interactive effects between the experimental condition and cognitive style in each cognitive load rating (Table 5). The ANOVA source of variation results indicated no interaction effects regarding intrinsic load, $F(3,161) = 0.767$, $p = 0.514$, partial $\eta^2 =$

0.014. However, the main effect of the group treatment was statistically significant, $F(3,161) = 2.686$, $p = 0.048$. Those in the NSG ($M = 19.93$, $SD = 3.619$) had significantly higher intrinsic load than did those in the ASG ($M = 17.05$, $SD = 4.889$), $p = 0.042$ (Table 2). There were no interaction effects concerning extraneous load, $F(3,161) = 0.305$, $p = 0.822$, partial $\eta^2 = 0.006$. There were no interaction effects regarding performance load, $F(3,161) = 0.130$, $p = 0.942$, partial $\eta^2 = 0.002$. However, a main effect of the group treatment was statistically significant, $F(3,161) = 4.336$, $p = 0.006$. Those in the NSG ($M = 28.05$, $SD = 4.93$) had significantly higher performance load than did those in the SBG ($M = 23.47$, $SD = 8.11$), $p = 0.012$; SBSAG ($M = 23.91$, $SD = 7.24$), $p = 0.029$; and ASG ($M = 23.81$, $SD = 5.99$), $p = 0.025$ (Table 2). There were no overall interaction effects on cognitive load, $F(3,161) = 0.501$, $p = 0.682$, partial $\eta^2 = 0.009$. However, a main effect of the experimental treatment was statistically significant, $F(3,161) = 3.103$, $p = 0.028$. Those in the NSG ($M = 71.75$, $SD = 10.46$) had significantly higher overall cognitive loads than did those in the ASG ($M = 62.81$, $SD = 14.35$), $p = 0.043$ (Table 2).

Discussion and conclusions

Research question one

First, the learners' performances indicated that those who received attention cueing failed to optimize their conceptual understanding and did not outperform those learners who did not receive attention cueing. The results somewhat echoed the results of previous studies (e.g., Crooks et al., 2012; de Koning et al., 2011a; Kriz & Hegarty, 2007; Lin & Atkinson, 2011; Moreno, 2007). One possible explanation is that merely providing attention cueing may only direct learners' attention to the essential elements without guaranteeing that learners constructed accurate mental representations and enhanced conceptual understanding (de Koning et al., 2009; Harp & Mayer, 1998; Kriz & Hegarty, 2007). Secondly, providing verbal text may be sufficient for learners to construct mental imagery (Plass et al., 2003), with the addition of visual representations with attention cueing being redundant. When the verbal and visual representations presented the same information, the learners applied cognitive resources to process both the visual and verbal information and left the remaining resources unavailable for helpful information processing. Then, the information presented might be redundant (Hegarty et al., 2003; Imhof et al., 2013).

Secondly, those who received dynamic contrast cueing (i.e., ASG) did not significantly outperform those who received visual contrast cues (i.e., SBSAG). The results somewhat echoed the results of previous studies (e.g., Hegarty et al., 2003; Tversky, Morrison, & Bétrancourt, 2002) in which animation was not superior to static diagrams in promoting learning efficiency. Possibly learners focused more on the salient dynamic-blood-and-dynamic-arrow cues and less on the written text, resulting in limited integration of the visual and verbal representations. A second possible explanation is that the transiency of animation caused interference (e.g., Hegarty et al., 2003). The learners had to visually switch back and forth between the text and animation which may have caused them to miss some information (Hegarty et al., 2003; Johnson & Mayer, 2010).

Thirdly, the presence of integration cues failed to optimize conceptual understanding, but yielded similar performances in the matching and identification tests. Those who received integration cues were still unable to indicate the steps in blood circulation. It was possibly the diagrams on the tests were completely different from the pictures in the instrumentation, so the learners felt difficult to transfer what they had learned in their attempt to understand the flow of blood through the body.

Research question two

Generally speaking, those in the NSG had significantly higher cognitive loads than did those in the other three conditions. The results were somewhat in line with the studies of Amadieu et al. (2011) and Kalyuga et al. (1999), which showed that the presence of visual or dynamic contrast cues can help reduce mental loads as predicted.

Besides, those in the NSG did not report having a higher mental load when taking the retention test, which simply required them to recall what they had learned without requiring them to convert texts into images. However, they generally reported having a higher mental load when answering the pictorial recall, matching, and identification tests, all of which involved pictures. The pictures used in the dependent measures were completely different from those in the instrumentation. The learners had no images to retrieve from the instrumentation when answering the imagery-based questions which required them to convert written texts into mental images. Therefore, performing these tasks was evidently more mentally demanding.

Research question three

The high-visualizers outperformed the low-visualizers in all four conditions, but did not reach the level of significance. There were no interaction effects between the experimental treatment and visual style in regard to the total score and overall cognitive loads, implying that both the high- and low-visualizers benefited equally well and experienced similar cognitive load from attention cueing. Further examination of the learners' performance on each subcategory of the tests revealed that visual representation with animated cueing was redundant for the high-visualizers but probably compensated for the low-visualizers. Since the high-visualizers had strong cognitive abilities that better enabled them to construct mental animation, the dynamic contrast cues were likely redundant and caused interference. However, the dynamic contrast cues providing external representations helped the low-visualizers build up mental models (Höffler, 2010), develop greater conceptual understanding, and perform better (Höffler & Leutner, 2011; Höffler, 2010; Mayer, 2009). These findings were largely consistent with those of Hegarty et al. (2003) and Imhof et al. (2013), in which no interactive effects between experimental treatment and visual style were found. There was almost no evidence to suggest that attention cueing favors high-visualizers. Attention cueing probably plays no role when comparing both high- and low-visuospatial learners (Höffler, 2010).

In sum, regardless of learners' cognitive styles, the presence of attention cueing yielded similar effects among all the learners, while reducing their cognitive load.

Suggestions for future research

No statistical evidence was observed to support the idea that attention cueing optimizes learning and benefits high-visualizers. Future researchers can replicate the experiment by incorporating self- or instructional explanations (de Koning et al., 2010b) or presenting the material with high- or low-speed (de Koning et al., 2011a) to examine learners' learning efficiency.

References

Amadieu, F., Mariné, C., & Laimay, C. (2011). The Attention-guiding effect and cognitive load in the comprehension of animations. *Computers in Human Behavior, 27,* 36–40.

Boucheix, J. M., Lowe, R. K., Putri, D. K., & Groff, J. (2011). Cueing animation: Dynamic signaling aids information extraction and comprehension. *Learning and Instruction, 25,* 71–84.

Chen, N. S., Hsieh, S. W., & Kinshuk. (2008). Effects of short term memory and content representation type on mobile language learning. *Language Learning and Technology, 12*(3), 93–113.

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review, 3*(3), 149–210.

Crooks, S. M., Cheon, J., Inan, F., Ari, F., & Flores, R. (2012). Modality and cueing in multimedia learning: Examining cognitive and perceptual explanations for the modality effect. *Computers in Human Behavior, 28*, 1063–1071.

de Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2008). Attention cueing as a means to enhance learning from an animation. *Applied Cognitive Psychology, 21*, 731–746.

de Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2009). Towards a framework for attention cueing in instructional animations: Guidelines for research and design. *Educational Psychology Review, 21*, 113–140.

de Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2010a). Attention guidance in learning from a complex animation: Seeing is understanding? *Learning and Instruction, 20*, 111–122.

de Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2010b). Learning by generating vs. receiving instructional explanations: Two approaches to enhance attention cueing in animations. *Computers and Education, 55*, 681–691.

de Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2011a). Attention cueing in an instructional animation: The Role of presentation speed. *Computers in Human Behavior, 27*, 41–45.

de Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2011b). Improved effectiveness of cueing by self-explanations when learning from a complex animation. *Applied Cognitive Psychology, 25*, 183–194.

de Koning, B. B., & Tabbers, H. K. (2013). Gestures in instructional animations: A Helping hand to understanding non-human movements? *Applied Cognitive Psychology, 27*, 683–689.

Dorling Kindersley (2013). *Knowledge encyclopedia*. London, UK: Dorling Kindersley.

Felder, R. M., & Soloman, B. A. (1997). Index of learning styles questionnaire. Retrieved from http://www.engr.ncsu.edu/learningstyles/ilsweb.html

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A Theory of cognitive interest in science learning. *Journal of Educational Psychology, 90*(3), 414–434.

Hegarty, M., Kriz, S., & Cate, C. (2003). The Roles of mental animations and external animations in understanding mechanical system. *Cognition and Instruction, 21*(4), 209-249.

Herron, C. A. (1994). An Investigation of the effectiveness of using an advance organizer to introduce video in the foreign language classroom. *The Modern Language Journal*, *78*(2), 190–198.

Herron, C. A., York, H., Cole, S. P., & Linden, P. (1998). A Comparison study of student retention of foreign language video: Declarative versus interrogative advance organizer. *The Modern Language Journal, 82*(2), 237–247.

Höffler, T. N. (2010). Spatial ability: It's influence on learning, with visualizations—A Meta-analytic review. *Educational Psychology Review, 22*, 245–269.

Höffler, T. N., & Leutner, D. (2011). The Role of spatial ability in learning from instructional animations—Evidence for an ability-as-compensator hypothesis. *Computers in Human Behavior, 27*, 209–216.

Imhof, B., Scheiter, K., Edelmann, J., & Gerjets, P. (2013). Learning about locomotion patterns: Effective use of multiple pictures and motion indication arrows. *Computers and Education, 65*, 45–55.

Johnson, C. I., & Mayer, R. E. (2010). Applying the self-explanation principle to multimedia learning in a computer-based game-like environment. *Computers in Human Behavior, 26*, 1246–1252.

Jones, L. C. (2009). Supporting student difference in listening comprehension and vocabulary learning with multimedia annotation. *CALICO Journal, 26*(2), 267–289.

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology, 13*, 351–371.

Kriz, S., & Hegarty, M. (2007). Top-down and bottom-up influences on learning from animation. *International Journal of Human-Computer Studies, 65*, 911–930.

Leutner, D., & Plass, J. L. (1998). Measuring learning styles with questionnaires versus direct observation of preferential choice behavior in authentic learning situations: The Visualizer verbalizer behavior observation scale (VV-BOS). *Computers in Human Behavior, 14*(4), 543–557.

Lin, L., & Atkinson, R. K. (2011). Using animations and visual cueing to support learning and scientific concepts and processes. *Computers and Education, 56*, 650–658.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge, MA: Cambridge University Press.

Mayer, R. E., & Moreno, R. (2010). Techniques that reduce extraneous cognitive load and manage intrinsic cognitive load during multimedia learning. In J. L. Plass, R. Moreno, & R. Brunken (Eds.), *Cognitive load theory* (pp. 131–152). New York, NY: Cambridge University Press.

Moreno, R. (2007). Optimizing learning from animations by minimizing cognitive load: Cognitive and affective consequences of signaling and segmentation methods. *Applied Cognitive Psychology, 21*, 765–781.

Moreno, R., & Mayer, R. E. (2010). Techniques that increase generative processing in multimedia learning: Open questions for cognitive load research. In J. L. Plass, R. Moreno, & R. Brunken (Eds.), *Cognitive load theory* (pp. 153–177). New York, NY: Cambridge University Press.

Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A Cognitive load approach. *Journal of Educational Psychology, 84*, 429–434.

Paivio, A. (1986). *Mental representation: A Dual coding approach*. Oxford, UK: Oxford University Press.

Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (1998). Supporting visual and verbal learning preferences in a second-language multimedia learning environment. *Journal of Educational Psychology, 90*(1), 25–36.

Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (2003). Cognitive load in reading a foreign language text with multimedia aids and the influence of verbal and spatial abilities. *Computers in Human Behavior, 19*, 221–243.

Tabbers, H. K., Martens, R. L., & van Merriënboer, J. J. G. (2004). Multimedia instructions and cognitive load theory: Effects of modality and cueing. *British Journal of Educational Psychology, 74*, 71–81.

Tversky, B., Morrison, J. B., & Bétrancourt, M. (2002). Animation: Can it facilitate? *International Journal of Human-Computer Studies, 57*, 247–262.

Wu, M. L., & Tu, J. T. (2006). *SPSS and statistical application analysis*. Taipei, Taiwan: Wu-Nan.