Park, S. (2015). The Effects of Social Cue Principles on Cognitive Load, Situational Interest, Motivation, and Achievement in Pedagogical Agent Multimedia Learning. *Educational Technology & Society, 18* (4), 211–229.

The Effects of Social Cue Principles on Cognitive Load, Situational Interest, Motivation, and Achievement in Pedagogical Agent Multimedia Learning

Sanghoon Park

Department of Educational and Psychological Studies, University of South Florida, USA // park2@usf.edu

ABSTRACT

Animated pedagogical agents have become popular in multimedia learning with combined delivery of verbal and non-verbal forms of information. In order to reduce unnecessary cognitive load caused by such multiple forms of information and also to foster generative cognitive processing, multimedia design principles with social cues are suggested (Mayer, 2014a). This study presents the design model of pedagogical agent multimedia learning by using four design principles based on social cues. Then reported are the findings of a study examining the effects of the pedagogical agent multimedia learning on perceived cognitive load, situational interest, motivation, and achievement. One hundred twenty seven college undergraduate students enrolled in four "Computer literacy" classes participated in this study and were randomly assigned to one of the six conditions in which on-screen images (image vs. no image) and narrations of a pedagogical agent (human voice narration, on-screen text, no narration) were presented in different levels. The results indicated that, overall, the presence of images does not significantly affect perceived cognitive load, situational interest, motivation, or achievement. However, the form of narration influenced the four outcome measures differently. The use of human voice narrations presented by a pedagogical agent was effective to reduce the perceived cognitive load compared to on-screen text narration and no narration conditions. Human voice narration by a pedagogical agent was also found to promote learners' situational interest, which is negatively correlated to cognitive load. The personalized narration was found to improve learners' motivation in terms of relevance and confidence whether presented by a pedagogical agent or in on-screen text although no significant differences were found in the recall test and the comprehension test.

Keywords

Cognitive load, Social cues, Generative processing, Pedagogical agent, Multimedia learning, Motivation

Introduction

The use of animated pedagogical agents in multimedia learning environments has increased as new technologies have made them more accessible (Gholson & Craig, 2002; Johnson, Rickel, & Lester, 2000). Pedagogical agents are animated life-like characters enabled with speech, gesture, movement, and human-like behaviors (Sweller, Ayres, & Kalyuga, 2011) and designed to facilitate learning in multimedia learning environments (Johnson et al., 2000). Pedagogical agents can embody different pedagogical roles to support learners by supplanting, scaffolding, coaching, testing, or demonstrating or modeling a procedure (Schroeder & Adesope, 2014). Previous studies have claimed the positive influences of pedagogical agents on student motivation and interest (Atkinson, 2002; Moreno, 2005) and also have indicated positive effects on student attitude toward learning and performance (Baylor, 2002a, 2002b; Baylor & Ryu, 2003; Moreno et al., 2001). However, other studies reported that pedagogical agents in multimedia learning could cause unnecessary cognitive load (Choi & Clark, 2006; Clark & Choi, 2005) called extraneous cognitive load. For example, the split-attention effect could occur when multiple sources of information are presented in split-attention without being integrated (Ayres & Sweller, 2014). The modality effect also can be caused when multiple sources of information are presented in single-modality not in dual modality (Low & Sweller, 2014). Both split-attention effect and modality effect are considered cognitive load effects caused by information presented through multiple information sources.

According to cognitive load theory (CLT), our brain utilizes two primary types of memory, the working memory and the long term memory, to process, store, and access information (Kalyuga, 2011; Sweller, 2005; Sweller, van Merriënboer, & Paas, 1998). Due to the limited capacity of the working memory, learners must cope with a certain level of cognitive load to process newly presented information. In pedagogical agent multimedia learning, both auditory and visual channels of information can be engaged in working memory from two different sources that are pedagogical agent and on-screen multimedia material, thus influence learners' cognitive load as a whole. Cognitive load theorists (Pass, Renkl, & Sweller, 2003; Sweller, 1999, 2005) agree that three different types of cognitive load need to be considered in designing instruction: (a) intrinsic cognitive load, (b) extraneous cognitive load, and (c) germane cognitive load. Intrinsic cognitive load is imposed by the intrinsic nature of presented information or learning task itself and should be reduced (i.e., task difficulty). Extraneous cognitive load results from the ineffective instructional design and needs to be prevented (e.g., format of instructional materials). Germane cognitive load is also imposed by instructional design but is effective for learning (e.g., a learner's effortful process of understanding). The distinction between intrinsic cognitive load and germane cognitive load is not clearly made (see Sweller, Ayres, & Kalyuga, 2011) because germane cognitive load is not imposed by the nature and structure of the learning materials. However, germane cognitive load has been associated with various additional cognitive activities that are designed to foster schema acquisition (Kalyuga, 2010). Therefore, it would be reasonable to consider germane cognitive load as sources of auxiliary cognitive activities to enhance learning outcomes or to increase learner motivation (Kalyuga, 2010).

Applying the types of cognitive load to designing multimedia learning environments, Mayer (2009, 2014b) suggested three kinds of cognitive processing demands in his cognitive theory of multimedia learning (CTML) that are extraneous processing, essential processing, and generative processing (also see Moreno & Mayer, 2010). Each of the kinds corresponds to each type of aforementioned cognitive loads (Mayer, 2014b). According to the CTML, people learn with multimedia presentations based on three assumptions. First, people learn by processing visual/ pictorial material and auditory/verbal material through separate channels. Second, people learn by processing limited amount of information in each channel at one time. And lastly, people learn by actively processing cognitive resources during learning, including selecting relevant information, organizing selected material into a coherent mental representation, and integrating incoming material with existing knowledge (Mayer, 2014b). Based on a central tenet common to CLT and the CTML, Mayer (2014b) summarized three demands on cognitive capacity during multimedia learning (Table 1). The Table 1 presents three types of demands on learners' information processing during learning using the terminology of the CTML and CLT.

Table 1. Three demands on cognitive capacity during multimedia learning (Mayer, 2014b)

Name	Description	Caused by	Learning processes	Example	Cognitive load
Extraneous processing	Cognitive processing that is not related to the instructional goal	Poor instruction al design	None	Focusing on irrelevant pictures	Analogous to extraneous cognitive load
Essential processing	Cognitive processing to represent the essential presented material in working memory	Complexity of the material	Selecting	Memorizing the description of essential processing	Analogous to intrinsic cognitive load
Generative processing	Cognitive processing aimed at making sense of the material	Motivation to learn	Organizing and integrating	Explaining generative processing in ones' own words.	Analogous to germane cognitive load

Strategies and techniques to meet each of the demands have been empirically tested in a number of studies. As a result, Mayer (2014b) suggested three categories of multimedia design principles based on three different learning scenarios. For example, the coherence principle, the signaling principle, the redundancy principle, the spatial contiguity principle, and the temporal continuity principle were suggested as principles for reducing extraneous cognitive load. For managing intrinsic cognitive load, suggested were the segmenting principle, the pretraining principle, and the modality principle. The third category of principles for fostering germane cognitive load includes the multimedia principle, the personalization principle, the voice principle, the embodiment principle, the guided discovery principle, the self-explanation principle, and the drawing principle (for details about each principle, see Mayer, 2014b).

In pedagogical agent multimedia learning, many of the aforementioned principles have been studied because of the nature of pedagogical agent and the instructional messages presented through verbal and non-verbal forms. For example, the signaling principle was tested as a strategy to reduce extraneous cognitive load by manipulating a pedagogical agent's movement and pointing gesture (Choi & Clark, 2006; Johnson, Ozogul, Moreno, & Reisslein, 2013). Also the modality principle in pedagogical agent multimedia learning has been examined was a way to manage intrinsic cognitive load by presenting information through two different sources, voice narration or on-screen text. (Moreno, 2002; Moreno, Mayer, & Lester, 2000; Moreno, Mayer, Spires, & Lester, 2001). The study findings were congruent with previous findings on modality effects in multimedia learning (Mayer, 2009; Moreno & Mayer, 1999; Mousavi, Low, & Sweller, 1995). Germane cognitive load in CLT represented as generative cognitive processing in Mayer's CTML, has been studied by manipulating germane sources of load (Renkl, Atkinson, & Große, 2004; Gerjets & Hesse, 2004; Berthold & Renkl, 2009). Several studies examined the learning effects of combining strategies of reducing extraneous load and increasing germane load so that students' cognitive resources can be redirected from irrelevant to relevant schema acquisition activities (Seufert & Brünken, 2006; Seufert, Jänen, & Brünken, 2007). However, few studies have been conducted on the strategies for generative cognitive processing aimed to foster germane cognitive load in pedagogical agent multimedia learning. Recently, Mayer and Estrella (2014) conducted a study to determine the effects of emotional design features in a multimedia lesson, but their study did not involve pedagogical agent multimedia learning.

Pedagogical agent multimedia learning model with social cue-based multimedia design principles

The goal of fostering generative cognitive processing is to increase germane cognitive load and engage students into learning by organizing and integrating information presented by a pedagogical agent and on-screen multimedia material. Based upon the framework of social cues in multimedia learning (Figure 1), and the four design principles derived from the framework, the researcher developed the pedagogical agent multimedia learning model.

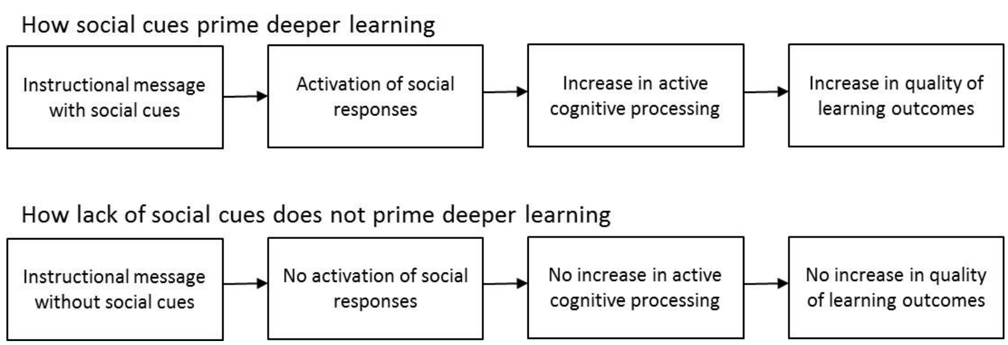

Figure 1. The presence or absence of social cues affecting learning (Mayer, 2014a)

Multimedia principle

The multimedia principle supports the notion that learning with words and pictures is more effective than learning with words alone (Butcher, 2014). However, the principle currently refers more broad forms of visual, verbal, and textual content and provides a context for research examining the optimal design of multimedia learning materials (Butcher, 2014). Hence, it becomes critical to examine the conditions when and how the multimedia principle best applies (Butcher, 2014). In other words, the multimedia principle must be considered in terms of the content and the roles of images and text, and how they support or interact each other.

Personalization principle

The personalization principle explains that people learn more deeply when the messages in multimedia learning are designed in conversational style than formal style (Mayer, 2014b). Conversational style can be designed by using words such as "you" and "I" or by presenting the instructor's direct-self revealing comments to learners (Moreno & Mayer, 2000; Mayer, 2014b). Previous studies used personalized messages in the form of on-screen text or voice narration (Moreno & Mayer, 2000, 2004).

Voice principle

The voice principle is that people learn more deeply when the words in a multimedia message are delivered in a human voice than in a machine voice (Mayer, 2014b). It supports a sense of social presence, hence human voice helps a learner feel a social response to the presented message.

Embodiment principle

The embodiment principle is that people learn more deeply when a pedagogical agent on-screen presents humanlike gesturing, movement, eye contact, and facial expressions (Mayer, 2014b). The on-screen agent could be designed in the form of a static image that shows no movement or could be designed to exhibit facial expressions, gestures, and movements.

Figure 2 illustrates the model for pedagogical agent multimedia learning with two sources of information influencing learners' generative cognitive processing and learning. According to social cue principles, first, a pedagogical agent's personalized human voice narration and human like gestures/expressions stimulate learners' interest and motivation. Second, multimedia materials (images and texts) presented on-screen also affect the learners' interest and motivation. The instigated learning interest and motivation further promote the use of generative cognitive processing, which is analogous to germane cognitive load in CLT.

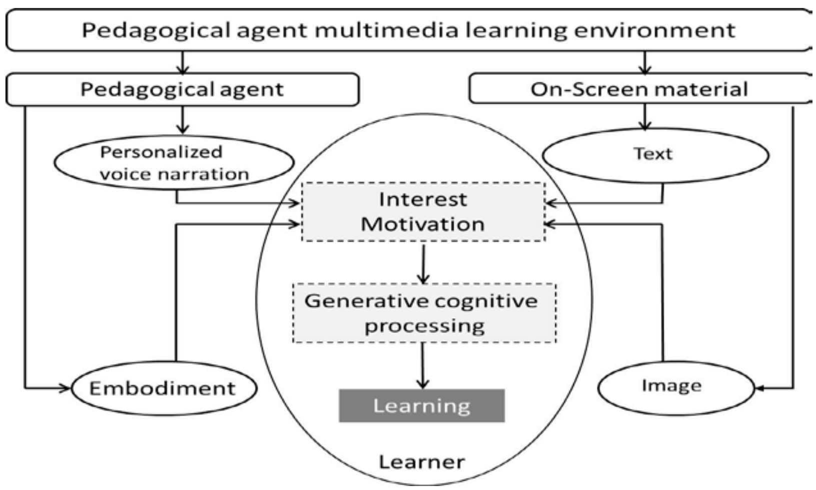

Figure 2. Pedagogical agent multimedia learning design model based on social cue principles

As depicted in the model, a rationale for implementing social cue principles in pedagogical agent multimedia learning is that both pedagogical agent and on-screen materials are intended to increase learner's interest and motivation. Therefore, the concepts of interest and motivation need to be discussed in detail.

Interest and motivation

Individual interest and situational interest

According to Krapp (2002), interest is a relational construct that consists of a more or less enduring relationship between a person and an object. This relationship is recognized by specific activities that may comprise concrete actions and abstract mental operations. Consequently the concept of interest may range from a single, situation-specific person-object relation (conceptualized as situational interest) towards the development of value beliefs in particular domains (conceptualized as individual interest). From the view of individual interest, interest is implied as a characteristic of person. It is specific to individuals, developed slowly, tends to be long lasting, and is triggered by an individual's predisposition (Renninger et al., 1992; Schiefele, 1998; Schraw & Lehman, 2001; Silvia, 2001). For example, learners who are already interested in a topic or an activity pay more attention and acquire more knowledge than participants without such interest. Schiefele (1991, 1999) explained this with two subcomponents of individual interest; a feeling-related valences and a value-related. Although individual interest can be assessed through a learner analysis process by asking several background questions or administering a simple questionnaire (Keller, 1983), it is not easy to incorporate strategies to improve individual interest in designing learning material because individual interest refers to a student's relatively enduring preference for different topics, tasks, or contexts that has been developed for a substantial period of time (Hidi & Renninger, 2006; Krapp, 1999; Tobias, 1994).

Situational interest is a prior foundation of individual interest (Krapp, 1999; 2002). When contents of a learning material is not a subject area in which the learner has established individual interest, the interesting factors in the subject learning situation is necessary to awake the interest for a short or longer period of time. The central psychological process "Internalization" supports the transformation process of situational interest into long-lasting individual interest as described in Figure 3. Situational interest is generated as a result of interestingness of situation. It is caused primarily by certain conditions and concrete objects in the environment, triggered by environmental factors, elicited by certain aspects of a situation, and it is assumed to contribute to the interestingness of the situation (Harp & Mayer, 1997; Hidi & Anderson, 1992; Krapp, 1999, 2002; Renninger et al., 1992; Schraw & Lehman, 2001; Silvia, 2001). While individual interest is a relatively stable evaluative orientation towards certain domains, situational interest is formed if an emotional state aroused by specific features of an activity or a task. Figure 3 illustrates the relationship between individual interest and situational interest.

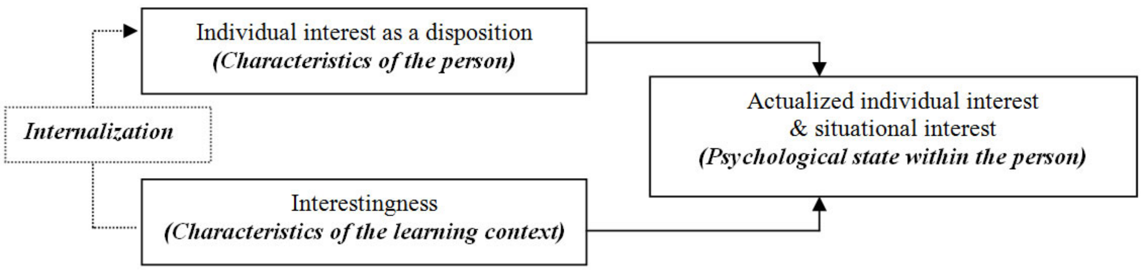

Figure 3. Individual interest and situational interest (Krapp et al., 1992)

Building upon previously conducted research on interest and development, Hidi and Renninger (2006) proposed four-phase model of interest development that describes phases of situational interest and individual interest in terms of affective and cognitive processes. The four-phase model provides a rationale for identifying early phases of interest development in terms of affect or liking. The model offers description of each phase, information about the type of support that a person in each phase of interest typically needs, and possible ways to design educational or instructional conditions to support interest development from situational interest to individual interest. The first two phases explains situational interest (triggering situational interest and maintaining situational interest). Then the last two phases suggest individual interest (emerging individual interest and well-developed individual interest).

ARCS Motivation model

In multimedia learning, motivation refers to how a learner initiates, energizes, maintains goal directed behaviors, and exerts effort to make sense of the instructional messages (Mayer & Estrella, 2014). Keller (2010) defined it with two elements, "direction" and "magnitude" of behaviors, and explained that motivation helps people choose goals to pursue and actively and intensively engaged them while pursuing the goals. According to Keller (2010), the concept of motivation is sorted into four categories that are Attention, Relevance, Confidence, and Satisfaction. Table 2 shows the definition of each category of the ARCS model. Among the four categories, attention refers to stimulating and sustaining a learner's curiosity and interest while studying a lesson. People are more interested in specifics rather than in abstractions, hence using specific people or illustrating ideas with concrete examples or visualizations such as stories or images can be used to gain a learner's attention.

Table 2. ARCS model categories and definitions (Keller, 2010)

Category	Definition
Attention	Capturing the interest of learners; stimulating the curiosity to learn
Relevance	Meeting the personal needs/goals of the learner to effect a positive attitude
Confidence	Helping the learners believe/feel that they will succeed and control their success
Satisfaction	Reinforcing accomplishment with internal and external rewards

Gaining situational interest and attention is the first step for students to be motivated. Keller (2010) further argued that achieving the other three categories, relevance, confidence, and satisfaction, is essential for learning motivation in a lesson. Because of the commonalities between situational interest and attention, this study considers attention as an outcome of situated interest derived from interacting with text and images presented on-screen.

Research purpose and questions

As Mayer (2014a) pointed out, generative cognitive processing is essential in learning because intended learning outcomes may not be achieved if a learner experiences "generative underutilization." Generative underutilization occurs when a learner has cognitive capacity available for generative processing but does not exert the effort to engage in learning due to the insufficient interest or lack of motivation to engage in germane cognitive activities (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Gerjets, Scheiter, & Catrambone, 2004). Mayer (2014a) suggested two types of design techniques to foster generative processing and reduce the possible "generative underutilization" problem: instructional design techniques and learning strategies. Instructional design techniques guide multimedia learning designing principles based on social cues (Mayer, 2014a) and they include the multimedia principle, the personalization principle, the voice principle, and the embodiment principle. On the other hand, learning strategies focus on supporting learners' cognitive involvement by implementing cognitive learning activities based on the guided discovery principle, the self-explanation principle, and the drawing principle. According to Moreno (2006), however, adding learning strategies to cognitive activities has not been found necessarily helpful for learners. Since then, cognitive activities have been studied widely in multimedia learning (Mayer, 2009; Sweller, Ayres, & Kalyuga, 2011) yet, social considerations that affect the learners' interest and motivation to engage in cognitive processing has not been emphasized much despite its' critical role in learning (Krämer, 2010; Mayer, Fennel, Farmer, & Campbell, 2004).

In order to ensure that a learner is actively involved in generative cognitive processing and fosters germane cognitive load, it is essential that the learner is ready and willing to spend his cognitive resources on generative processing (Moreno & Mayer, 2010) so that he can produce better achievement (Mayer & Estrella, 2014). The present study examined the effectiveness of the four social cue-based multimedia design principles - the multimedia principle, the personalization principle, the voice principle, and the embodiment principle - integrated in pedagogical agent multimedia learning on learners' both cognitive and affective aspects of learning. Specifically, this study attempted to measure interest and motivation separately based on the interest theory and the ARCS motivation theory. According to Hidi and Renninger (2006) and Keller (2010), a learner's "willingness" to exert an effect begins with "interest." Hidi and Renninger (2006) suggested in their interest development model that "situational interest" has to be triggered and maintained before being developed to "individual interest." Keller (2010) in his ARCS motivation model also explained that "capturing interest," "stimulating inquiry," and "maintaining attention" are the first steps that influence motivation to learn. Therefore, measuring situational interest separately from motivation will help understand how two different development stages of motivation affect cognitive load differently.

Based on the pedagogical agent multimedia learning design model depicted in Figure 2, the researcher developed a Web-based learning material on Intellectual property. Then the effects of social-cue principles applied to the design of learning material were examined on learners' perceived cognitive load, situational interest, motivation, and achievement. The following research questions were formulated to explore this issue.

RQ1. What is the effect of multimedia design principles using social cues on cognitive load in pedagogical agent multimedia learning?
RQ2. What is the effect of multimedia design principles using social cues on situational interest in pedagogical agent multimedia learning?
RQ3. What is the effect of multimedia design principles using social cues on motivation in pedagogical agent multimedia learning?
RQ4. What is the effect of multimedia design principles using social cues on achievement in pedagogical agent multimedia learning?

Method

Research design

The study used a 2 × 3 factorial design as shown in Table 3. The study variables included the use of images (presence vs. absence) to test the multimedia principle and the source of narrations (Human voice narration delivered by a pedagogical agent, text narration delivered on-screen, no narration) to test the social cue principles including the personalization principle, the voice principle, and the embodiment principle. This study employed a randomized group post-test design. In order to explore the established research questions, participants were randomly assigned into the one of the six conditions (A through F) based on the sequence of their entry to the research lab.

Table 3. Research design

Group	Random assignment	Condition	Treatment	Posttest
Computer literacy class students	R	A	X^a_1 Y^b_1	O_1
		B	X_1 Y_2	O_2
		C	X_1 Y_3	O_3
		D	X_2 Y_1	O_4
		E	X_2 Y_2	O_5
		F	X_2 Y_3	O_6

Note. [a] First independent variable: the use of graphic (1: presence, 2: absence); [b] Second independent variable: the source of narration; (1: pedagogical agent, 2: text narration, 3: no narration).

Participants

The participants were 127 college undergraduate students enrolled in "Computer literacy" classes in a large public university located in the southeastern United States. This course was one of the required courses for the undergraduate students. All participants were recruited from ten sections of the course and offered extra credits as compensation. Only participants who agreed to participate in the study by signing the consent form were included in the final data analyses. A total of 136 students voluntarily participated at the beginning of the study. Of these, 127 participants were included in the final data analyses because nine students didn't complete the post questionnaire. All of the 127 participants were undergraduate students. The average age of the sample was 19.72 years (SD = 1.96). Among those 127 participants, 63.0% were Caucasian, 19.7% were African-American, 11.0% were Hispanic/Latino, 2.4% were Asian/Asian American, 1.6% were bi-racial, and 2.3% were other ethnicity groups. There were 60.6% of male students and 39.4% of female students. The majority of the participants were sophomores (43.3%) with 21.3% freshmen, 20.5% juniors, and 15.0% seniors.

Research material

The topic of instructional material used in this study was "Introduction to intellectual property." The topic consisted of three sub concepts of intellectual property including patent, trademark, and copyright. "Intellectual property" was selected for several practical reasons and theoretical reasons. First, the topic "Intellectual property" had been one of the topics in the Computer literacy class. Therefore, students were aware of the topic, but not familiar with detailed information, specifically in the areas of patents, trademarks, and copyrights. Second, this topic was related to the students' everyday life regarding how to use computer applications without violating any legal and ethical issues. Third, in order to fulfill the primary goal of this study and investigate the effect of social cue principles in pedagogical agent multimedia learning, instructional text for which students presumably had low levels of prior knowledge and low interest was used.

Instructional material on Intellectual property consisted of three learning phases: (1) Introduction phase: Students were given a brief introduction about intellectual property and basic information containing history, related regulations, and examples. (2) Learning phase: Students were given a detailed explanation in regard to the three sub-concepts of intellectual property: patent, trademark, and copyright. (3) Test phase: After completing instructional material, students were given an opportunity to actually test what they had read in the instructional material.

The researcher developed a multimedia lesson consisting of 14 screen pages for each condition with two introduction slides (s1-s2), 11 learning material slides (s3-s13) and one test slide (s14). Each of the 11 learning material slides consisted of two types of information: expository information and supplementary information because the focus of the lesson presented in this study was concept learning. Three different types of "intellectual property" were presented on-screen in expository texts (Figure 4). Then supplementary texts were designed based on the personalization principle to provide examples and cases of copyright, trademark, and patent in a real life (Figure 5) and delivered in a human voice narration or on-screen text depending on the study condition. Unlike scientific expository text, learners in concept learning can form prototypes and exemplars of the concept by encountering varied instances of the concept (Ormrod, 2012). By presenting definitions and examples hand in hand, more effective concept learning can occur (Dunn, 1983; Tennyson, Youngers, & Suebsonthi, 1983).

> A patent as one of three main types of intellectual property gives an inventor the right for a limited period to stop others from making, using or selling an invention without the permission of the inventor. It is a deal between an inventor and the state in which the inventor is allowed a short term monopoly in return for allowing the invention to be made public. There are some special features of a patent in terms of its scopes. In addition, specific conditions must be fulfilled to get a patent. Patents as one of three main types of intellectual property are about functional and technical aspects of products and processes. Most patents are for incremental improvements in known technology - evolution rather than revolution. The technology does not have to be complex. Patent rights are territorial; a US patent does not give rights outside of the US. Patent rights last for up to 20 years in the US.

Figure 4. Example of expository text

> Here's something interesting… Do you drive your own car? You've probably never wondered who invented "power steering valves"? Well, let me tell you. Bishop power steering valves are used in about one fifth, or 20%, of the world's cars. A.E. Bishop & Associates, the company that makes the valves, receives a royalty payment of up to $1.00 for each unit someone manufactures and generates its financial return through effective use of intellectual property.
>
> The story goes that Arthur Bishop began developing and patenting automotive power steering systems after World War II. His company now has over 300 patents worldwide AND it makes about $5 million a year in royalties. This means that his company doesn't manufacture any products itself but licenses car and component manufactures and specialist manufactures of machinery around the world to use its designs. Obviously they make sure their patents are vigorously defended. And I can tell you that they prosecute many infringers. Infringers are people who try to use the valve without paying the royalty.

Figure 5. Example of supplementary text

The total number of images used in the material was 10, one in each of the slides s4-s13, which was presented in the identical way across the conditions A-C. The total word count of expository on-screen text was 1021 with an average of 92.82 in each of the slides s3-s13. The content of the expository on-screen text was identical across the conditions A-F. The total word count of supplementary text delivering the personalized narration (whether voice or on-text) was 1377 with an average of 125.18 in each of the slides s3-s13. The content of the personalized narration was identical in conditions A, B and D E. The summary of multimedia elements and design principles used in the six study conditions are presented in Table 4.

Table 4. Multimedia elements and design principle for study conditions

Conditions		Multimedia elements	Total number of elements	Average time (in minutes) taken to finish lesson	Design principles applied
Image	Condition A Voice narration with pedagogical agent	Cartoon image Expository information (on-screen text) Supplementary information (Human voice narration)	10 images 1021 words 1377 words	10.38 min	Multimedia principle Personalization principle /Embodiment principle / Voice principle (Pedagogical agent)
	Condition B On-screen text	Cartoon image Expository information (on-screen text) Supplementary information (on-screen text)	10 images 1021 words 1377 words	11.63 min	Multimedia principle Personalization principle (on-screen text)
	Condition C No narration or text	Cartoon image Expository information (on-screen text)	10 images 1021 words	11.76 min	Multimedia principle

No image	Condition D Voice narration with pedagogical agent	Expository information (on-screen text)	1021 words	10.68 min	
		Supplementary information (Human voice narration)	1377 words		Personalization principle / Embodiment principle / Voice principle (Pedagogical agent)
	Condition E On-screen text	Expository information (on-screen text)	1021 words	12.73 min	
		Supplementary information (on-screen text)	1377 words		Personalization principle (on-screen text)
	Condition F No narration or text	Expository information (on-screen text)	1021 words	12.76 min	No design principle used

In order to maximize the positive effect of combining auditory and visual information and also to minimize the influences of extraneous cognitive load caused by poor instructional design (Mayer, 2014b) such as a reverse modality effect, the instructional material was presented in a self-paced format. It also ensured that learners have time to transfer information from working to long-term memory without being affected by a working memory overload (Sweller, Ayres, & Kalyuga, 2011). Information on each screen was presented in the order of “expository information” to “supplementary information” to ensure that learners read or listen to the information in the same sequence. When supplementary information was presented in the form of human voice narration, a “Listen” button was shown on the Web material for students to click on to listen to the human voice narration after reading the expository information. Hence, students followed the sequence of “reading expository information” to “listening to agent delivering supplementary information.” When supplementary information was presented in the form of on-screen text, students were presented with the expository information first, then the supplementary information was presented afterward in the form of on-screen text. Therefore, students followed the sequence of “reading expository information” to “reading supplementary information.” Students were directed to go through all screens in the order from the introduction phase to the test phase using the “Next” button to prevent students from referring to the previous text while taking a test.

Independent variables

All six conditions used the same expository text on intellectual property. Then two independent variables, (1) images supporting the expository text and (2) the sources of narration, were manipulated differently in each of the six conditions. Images were intended to trigger learners’ interest in the expository text and also to help learners acquire the meaning of the concept explained in each screen. For this purpose, one cartoon image was presented on each screen in two levels (presence vs. absence).

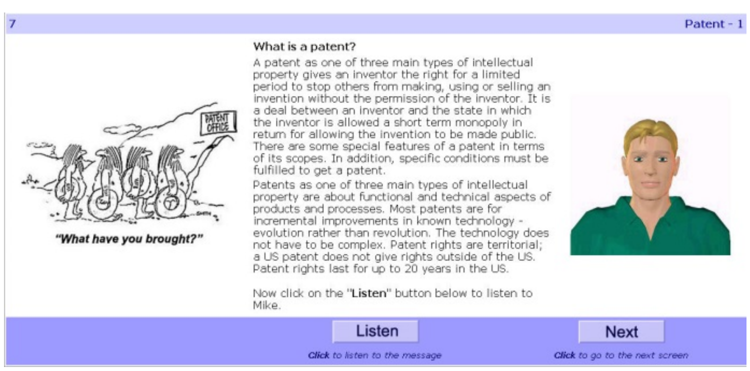

Figure 6. Condition A: Image and personalized human narration presented by an animated pedagogical agent

Narrations were presented in three different levels. First, personalized human voice narration was delivered by a pedagogical agent. Second, personalized text was presented on-screen without a pedagogical agent. The personalized voice narration and the personalized text delivered the identical message. Lastly, no verbal or text narration was presented. The personalized on-screen text condition was included to separate the personalized principle from the voice principle and the embodiment principle. The no narration condition was included in the study as a control group by excluding supplementary information, thus presenting only expository information. An example screenshot for each of the six conditions is presented in Figures 6 - 11.

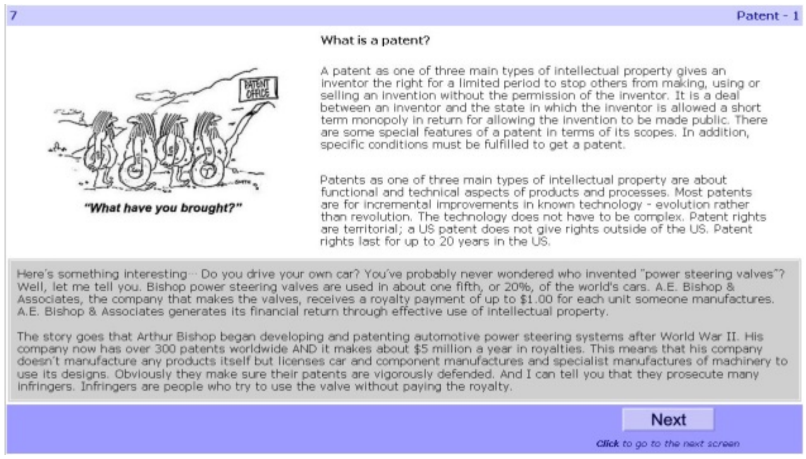

Figure 7. Condition B: Image and personalized on-screen text

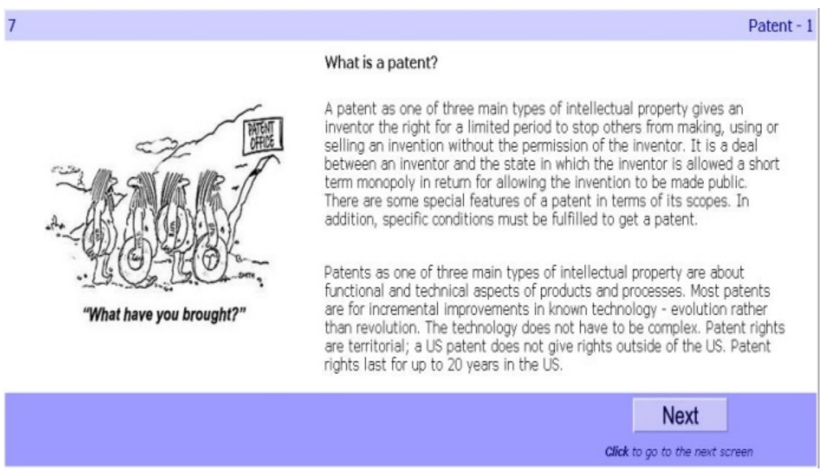

Figure 8. Condition C: Image and no personalized narration or text

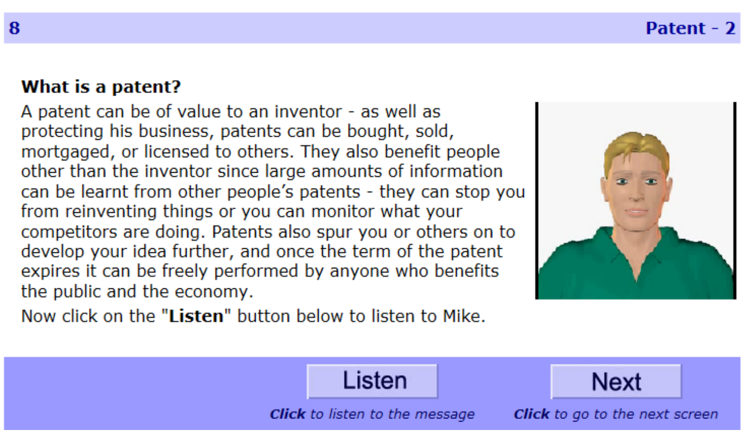

Figure 9. Condition D: No image and personalized human narration presented by an animated pedagogical agent

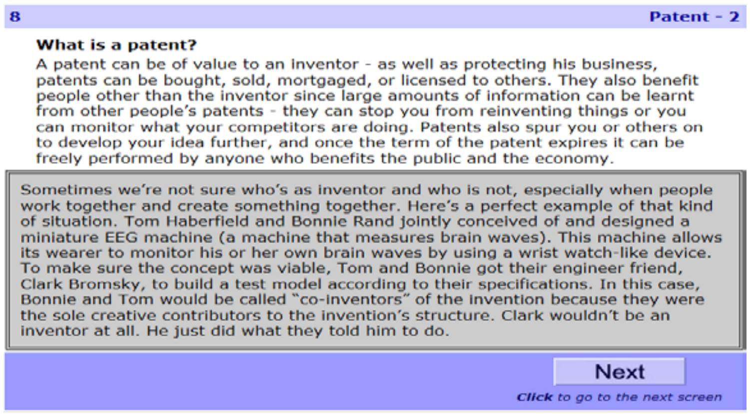

Figure 10. Condition B: No image and personalized on-screen text

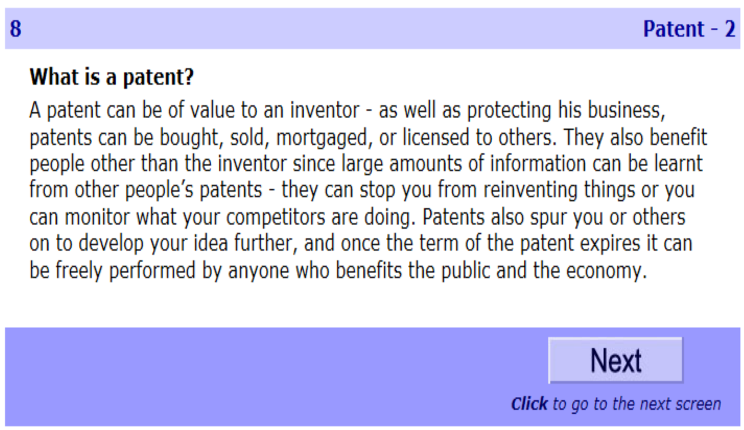

Figure 11. Condition C: No image and no personalized narration or text

Dependent variables

Dependent variables for the study included cognitive load, situational interest, motivation, and achievement.

Cognitive load

Perceived cognitive load was measured by using a single item student self-rating scale developed by Paas and van Merriënboer (1994). Although subjective rating scales are criticized not to provide information regarding which of the three types of cognitive load originated the reported mental effort (Bruüken, Seufert, & Pass, 2010), previous studies shown that this scale is valid, reliable, and sensitive to relatively small differences in cognitive load (Gimino, 2002; Paas, van Merriënboer, & Adam, 1994). In this study, the item asked the participants to use a nine-point Likert-type scale to identify the amount of mental effort they invested to study the instructional material. The cognitive load measures ranged from very, very low mental effort to very, very high mental effort.

Situational interest

The situational interest was measured from three aspects: arousal, involvement, and attention. In order to measure the arousal level, five items from the Activation-Deactivation Adjective Check List (AD-ACL) were used (Thayer, 1986). For example, "I felt active at the moment while I was studying." The reliability was .91. In order to measure participants' involvement, two dimensions (intensity and persistence) were considered based on Reynolds' distinction (Reynolds, 1992). The intensity dimension is measured by self-report items, and the persistence dimension is measured by means of recording the subjects' participating times (Schiefele & Krapp, 1996). In this study, the intensity dimension was assessed by two items "I was completely caught up in what I was studying", and "When learning from the material, I was concentrated". The reliability was .73. Attention was measured as part of situational interest because its' conceptual proximity to situational interest. Attention deals with the questions such as how to stimulate and sustain a learner's attention by using novel approaches, creating paradoxes, and using variations in presentation style (Keller, 2010). In order to measure participants' attention level, twelve attention sub scale from Keller's Instructional Material Motivation Survey (IMMS) was employed (Keller, 1993). For example, "I found something interesting at the beginning of this instructional material that got my attention." The response reliability was .83.

Motivation

Students' motivation toward to the instructional material was measured in three components of motivation: Relevance, Confidence, and Satisfaction based on the IMMS developed by Keller (1993). The responses ranged from one to five on a Likert scale with nine relevance component items, nine confidence component items, and six satisfaction component items. The reliability of IMMS based on Cronbach's alpha for each subscale was Relevance: .81, Confidence: .90, and Satisfaction: .92.

Achievement

Student achievement was measured on two levels: (1) recall test and (2) comprehension test. A recall test was designed to assess students' ability to recall as many keywords as possible from the instructional material on intellectual property. The comprehension of the instructional material was measured by a comprehension test that was designed to assess students' ability to select the correct information by applying what they learned from the instructional material, without further access to the material. Items included in this study were six true/false items, three multiple-choice items, and one open-ended question. True/false items were constructed to test students' ability to remember the factual knowledge about a patent, a trademark, and a copyright correctly. Multiple choice items were constructed to test students' ability to compare and evaluate related ideas and concepts of a patent, a trademark, and a copyright. One of the items was an open-ended question that referred to the relationship among intellectual property, a patent, a trademark, and a copyright. Students were requested to explain in writing how the intellectual property and three sub concepts are related. The purpose of the open-ended question was to assess students' general understanding of the main topic "Intellectual property." An example of the true/false item is "A trademark is any sign that includes words, logos, colors, slogans, three-dimensional shapes, but not sounds and gestures." (T/F). An example of the multiple choice items was "Which one of the followings is not an advantage of registering trademark? (1). Notice to the public of the registrant's claim of ownership of the mark. (2) A legal presumption of ownership nationwide. (3) The exclusive right to use the mark on or in connection with the goods or services set forth in the registration, and (4). Economic rewards for creator's efforts." Lastly, an open-ended question asked "Please describe in writing how the concepts of intellectual property, copyright, trademark, and patent are related each other."

Procedure

When participants logged on the computer, they were guided to the multimedia instructional material on the topic of "Intellectual Property." And they were asked a series of questions about their demographics, level of individual interest based, and prior learning experience with intellectual property. Then each participant was presented the instructional material corresponding to his/her treatment condition and told to begin the material. They were not allowed to take notes or refer to other resources. At the end of the study, participants were asked to respond to questionnaires for dependent measures.

Data analysis

The study was designed as a 2 × 3 factorial design. The variables included the use of images (presence vs. absence) and the source of narration (pedagogical agent, text without agent, no narration). First, preliminary data analyses were conducted to detect problematic observations and to assess violations of the assumptions for statistical procedures. In a primary data analysis, the main effect of two independent variables was conducted for four dependent variables: (1) perceived cognitive load, (2) situational interest score, (3) achievement score, and (4) motivation score. The significance level for all the analyses was set at $\alpha < .05$. Bonferroni adjustment was made when multiple comparisons are performed (Field, 2013).

Results

Prior to the main data analysis, the equivalence of treatment conditions in terms of pre-interest (individual interest) was verified. The level of pre-interest was measured using five feeling-related interest items and four value-related interest items based on Schiefele's definition of individual interest (1991, 1999). The reliability of each measure was .74 and .75 respectively in this study. The result of a one way between-groups multivariate analysis of variance showed no significant differences among the six conditions. Therefore, the level of pre-interest (individual interest) was confirmed equivalent among the six conditions in this study. Additionally, a missing value analysis, a case analysis, and a detection of violations of assumptions for the main dependent variables were conducted. The descriptive statistics for all dependent variables are presented in Table 5 according to the six conditions.

Table 5. Descriptive statistics for the dependent variables

			Conditions					
			Image			No image		
Dependent variables	Measures		Agent (n = 31)	Text (n = 16)	No (n = 17)	Agent (n = 31)	Text (n = 15)	No (n = 17)
Cognitive load [a]	Cognitive load	*M*	1.87	3.06	2.41	2.42	2.60	3.47
		SD	1.02	1.44	1.37	1.39	1.59	1.46
Situational interest [b]	Arousal	*M*	2.21	1.56	1.79	2.17	1.97	1.74
		SD	061	.57	.55	.64	.60	.67
	Involvement	*M*	2.58	2.10	2.44	2.58	2.27	2.26
		SD	1.03	.84	.66	.83	.53	.94
	Attention	*M*	3.47	2.94	2.84	3.13	2.86	2.67
		SD	.62	.46	.56	.57	.49	.76
Motivation [c]	Relevance	*M*	3.87	3.66	3.28	3.60	3.71	3.13
		SD	.69	.35	.52	.71	.56	.60
	Confidence	*M*	3.38	2.93	2.86	3.13	2.94	2.78
		SD	.53	.50	.72	.63	.71	.63
	Satisfaction	*M*	2.60	2.10	2.18	2.29	2.30	2.18
		SD	1.01	.58	.55	.62	.50	.50
Achievement	Recall test [d]	*M*	7.01	5.25	5.47	6.32	5.93	5.53
		SD	3.04	1.53	1.97	2.60	2.49	2.10
	Comprehen-sion test [e]	*M*	5.71	5.13	5.94	5.16	5.67	5.53
		SD	1.55	1.50	1.56	1.10	1.23	2.07

Note. [a] Possible range for cognitive load (1-9); [b] Possible range for learning interest (1-5); [c] Possible range for attitude (1-5); [d] Possible score range for recall test: Minimum: 2 , Maximum: 9; [e] Possible range for comprehension test (0-10).

RQ1. What is the effect of multimedia design principles using social cues on cognitive load in pedagogical agent multimedia learning?

A 2 x 3 between-groups ANOVA on cognitive load measure indicated no significant effect for images, F (1,121)= 2.32, $p = .13$. However, there was a significant main effect of the source of narrations, F(2, 121)= 4.88, $p < 0.01$, $\eta^2 = .08$. Further post-hoc analysis using a Bonferroni adjusted alpha level of 0.016 revealed that perceived cognitive load was significantly lower when human voice narration was presented by a pedagogical agent (M = 2.14, SD = 1.24) than when the narration (M = 2.94, SD = 1.49) was not presented . There was no significant difference found between the on-screen text narration condition (M = 2.84, SD = 1.51) and the no narration condition although the cognitive load was higher when no narration was presented than the on-screen text narration was presented.

RQ2. What is the effect of multimedia design principles using social cues on situational interest in pedagogical agent multimedia learning?

A factorial MANOVA indicated that there was no statistically significant difference of situational interest score between learners presented with images and learners not presented with images, Wilks' Lambda = .940, F (3,119) = 2.54, p = 0.06. A second factorial MANOVA revealed that there was a statistically significant difference of situational interest score among the three narration conditions, Wilks' Lambda = .792, F (6,238) = 4.902, $p < .001$, $\eta^2 = .11$. Follow-up ANOVA indicated that significant differences occurred in arousal, F (2,121) = 7.58, $p = 0.001$, $\eta^2 = .11$, and attention, F (2,121) = 10.68, $p < .001$, $\eta^2 = .15$.

Tukey HSD follow-up procedure indicated that arousal score for the pedagogical agent with human voice condition (M = 2.19, SD = .62) was significantly higher than both the on-screen text condition (M = 1.76, SD = .60) and the no narration condition (M = 1.77, SD = .60). For attention, the result indicated that the attention score for the pedagogical agent with human voice condition (M = 3.30, SD = .61) was significantly higher than both the on-screen text condition (M = 2.90, SD = .47) and the no narration condition (M = 2.76, SD = .66).

RQ3. What is the effect of multimedia design principles using social cues on motivation in pedagogical agent multimedia learning?

A factorial MANOVA indicated that there was no statistically significant difference of motivation score between learners presented with images and learners not presented with images, Wilks' Lambda = .985, F (3,119) = .599, p = .62. However, a factorial MANOVA revealed that there was a statistically significant difference of learners' motivation score among the three narration conditions, Wilks' Lambda = .789, F (6,238) = 4.99, $p < .01$, $\eta^2 = .11$. Follow-up ANOVA indicated that significant differences occurred in relevance, F (2,121) = 8.74, $p < .001$, $\eta^2 = .13$, and confidence, F (2,121) = 6.19, $p < .01$, $\eta^2 = .09$. Tukey HSD follow-up procedure indicated that relevance scores for the pedagogical agent with human voice condition (M = 3.73, SD = .71) and the on-screen text condition (M = 3.68, SD = .46) were significantly higher than the no narration condition (M = 3.21, SD = .56) respectively. For confidence, the result indicated that confidence score for the pedagogical agent with human voice condition (M = 3.25, SD = .59) was significantly higher than the no narration condition (M = 2.82, SD = .67). However, there was no significant difference found between the on-screen text condition (M = 2.94, SD = .60) and the no narration condition.

RQ4. What is the effect of multimedia design principles using social cues on achievement in pedagogical agent multimedia learning?

A 2 x 3 between-groups ANOVA on recall test scores revealed no significant effect for images, F (1,121) = .001, $p = .98$, but a significant effect for the source of narration, F (2,121) = 3.56, $p < 0.05$, $\eta^2 = .06$. However, further post-hoc analysis using a Bonferroni adjusted alpha level of 0.016 revealed no significant difference among the three narration conditions. Another 2 x 3 between-groups ANOVA on comprehension test scores revealed that there was no significant effect for images, F (1,121) = .25, p = .62, and no significant effect for the source of narration, F (2,121) = .55, p = .58.

Discussion

This study investigated the effects of multimedia design principles using social cues on learners' perceived cognitive load, situational interest, achievement, and motivation in pedagogical agent multimedia learning. Overall, the results indicated that using multimedia design principles with social cues increases situational interest and motivation in terms of relevance and confidence. Although the presence of images did not significantly affect the two dependent measures, the source of narration did influence them.

First, it should be noted that the overall cognitive load from all conditions were relatively low (the highest was 3.47 and the lowest was 1.87), which suggests that the material content was not too much difficult for participants to understand thus low intrinsic cognitive load. Yet students' perceived cognitive load was significantly different between the study conditions. When a personalized human voice narration was presented by a pedagogical agent along with images, students reported the lowest cognitive load whereas students reported the highest cognitive load when no images or narrations were presented (see Figure 12). But, when the personalized text is presented on-screen along with images, students perceived higher cognitive load than when no images were presented. Therefore, we can conclude that the personalization principle has to be applied to the pedagogical agent delivering human voice narration to increase the effectiveness of the multimedia design principles using social cues.

Second, the result of situational interest score analysis shows that learners reported scored significantly higher arousal and attention scores when narrations were presented by a pedagogical agent. The finding indicates that the pedagogical agent delivering human voice narration triggered students to be more interested in the learning material than other conditions. Situational interest is triggered as a result of short-term changes in affective and cognitive processing (Hidi & Renninger, 2006) while being involved in learning activities. The follow-up correlation analysis found a significantly negative correlation between perceived cognitive load and situational interest, r = -.417, n = 127, p < 0.001. It implies that highly triggered and maintained situational interest may have reduced perceived cognitive load in pedagogical agent multimedia learning and thus increase generative cognitive processing.

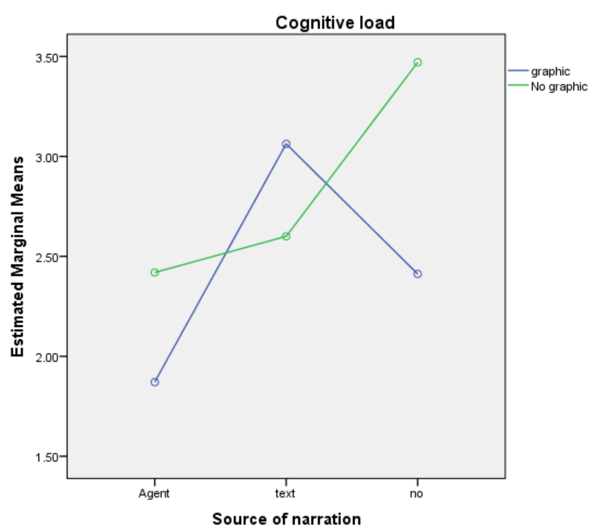

Figure 12. Cognitive load among the study conditions

Third, relevance was higher when narrations were delivered either by pedagogical agent's human voice or on-screen text. It is likely that students were able to link the presented concepts to the real examples provided in the narrations. Confidence was higher only when pedagogical agents delivered the narrations. The results suggest that pedagogical agents delivering narrations are effective in improving students' perception of relevance and confidence to the learning material. The follow-up correlation analysis showed a significantly negative correlations between perceived cognitive load and relevance, r = -.259, n = 127, p < 0.01 and also between perceived cognitive load and confidence,

$r = -.326$, $n = 127$, $p < 0.001$. It implies that the personalization principle whether used in human voice or in on-screen text can be effective to reduce perceived cognitive load in pedagogical agent multimedia learning and increase generative cognitive processing.

Although multimedia design principles with social cues were found effective to increase situational interest and motivation when applied with a pedagogical agent, no significant differences were found for the recall test and the comprehension test. The reason can be attributed to the four-phases of interest development (Hidi, & Renninger, 2006). Situation interest has to be triggered and maintained before being internalized to well-developed individual interest. In this study, learners showed higher arousal and attention to the learning material, but it is possible that the interest was triggered only by the supplementary information, and the triggered interest might have not been transferred to learning the main expository information. In future research, the triggering point of situational interest in different multimedia elements has to be examined so increase in situational interest can be attributed to the entire learning material, not part of it.

The findings of this study have several implications. First, the results of this study illuminate the importance of using multimedia principles with social cues to increase generative cognitive processing in pedagogical agent multimedia learning. Especially, the social cues can help promote interest and motivation to support concept learning rather than damaging learning. Second, the important finding is the negative correlations between cognitive load and situational interest or motivation. Future work is needed to establish a direct causal effect relationship between the variables.

Conclusion

The current study examined four multimedia design principles with social cues to promote generative processing in pedagogical agent multimedia learning. Future research needs to be conducted to verify the study findings. First, as this study mainly focused on applying the multimedia design principles with social cues to designing voice narration by a pedagogical agent and on-text narration, a no-social cue condition also needs to be considered in the future. For example, personalized human voice narrations and personalized machine voice narrations can be compared in different presentation modalities to build comprehensive understanding of the voice principle, and how it affects perceived cognitive load, interest, and motivation differently. Second, this study used a single subject rating method to measure the overall mental effort invested to learning the material, whereas future study would benefit from more contemporary instrument to measure different types of cognitive load separately (see Leppink, Paas, Van der Vleuten, Van Gog, & Van Merriënboer, 2013) and examine the relationship between motivation and each type of the cognitive loads. Third, the goal of the learning material was concept learning on the topic of intellectual property. This might have caused a little or no interaction between the elements in the learning material, thus reduced the perceived cognitive load. Future study should extend the scope of material content to other subject areas with high level of element interaction such as math or science so that students can be fully engaged in generative cognitive processing to solve a problem. Lastly, this study confirmed the equivalent level of individual interest across the conditions before the main analyses, yet the possible effect of prior knowledge was not considered. Additional research is needed to include a pretest to measure learners' prior knowledge and investigate how learners' prior knowledge and the multimedia design principles interact in multimedia learning.

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