Computers & Education 67 (2013) 239–249

Contents lists available at SciVerse ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Animated agents and learning: Does the type of verbal feedback they provide matter?

Lijia Lin [a,*], Robert K. Atkinson [b], Robert M. Christopherson [c], Stacey S. Joseph [c], Caroline J. Harrison [d]

[a] School of Psychology and Cognitive Science, East China Normal University, 3663 N. ZhongShan Rd., Shanghai 200062, China
[b] School of Computing, Informatics, and Decision Systems Engineering, Arizona State University, USA
[c] Mary Lou Fulton Teachers College, Arizona State University, USA
[d] School of Letters and Sciences, Arizona State University, USA

ARTICLE INFO

Article history:
Received 22 December 2012
Received in revised form
14 April 2013
Accepted 15 April 2013

Keywords:
Multimedia/hypermedia systems
Human–computer interface
Interactive learning environments
Teaching/learning strategies
Architectures for educational technology system

ABSTRACT

The current study was conducted to investigate the effects of an animated agent's presence and different types of feedback on learning, motivation and cognitive load in a multimedia-learning environment designed to teach science content. Participants were 135 college students randomly assigned to one of four experimental conditions formed by a 2 × 2 factorial design with agent presence as one factor (agent vs. no-agent) and type of verbal feedback it provided as the other factor (simple feedback vs. elaborate feedback). Results revealed that participants who learned with the animated agent that delivered elaborate feedback had significantly higher scores on a learning measure compared to participants who learned with an agent that provided simple feedback. The results are interpreted from both social agency and cognitive load theoretical perspectives.

1. Introduction

As researchers continue to investigate methods and guidelines to increase the effectiveness of learning environments, attention is being focused on how motivation, social interaction and cognitive processes impact learning in multimedia environments (Mayer, Sobko, & Mautone, 2003; Moreno, 2007; Moreno & Mayer, 2007). Multimedia environments provide an interface that incorporates words and pictures in ways that can potentially capitalize on these factors and enhance learning (Mayer, 2005). For example, researchers have explored using animated pedagogical agents to enhance social interaction between the computer and the learner and promote learning processes (Atkinson, 2002; Craig, Gholson, & Driscoll, 2002; Dunsworth & Atkinson, 2007). An animated pedagogical agent is a lifelike character that provides instructional information through verbal and nonverbal forms of communication. An agent incorporates some or all of the following features: (a) a human-like look, (b) locomotion, (c) goal-directed gestures, (d) facial expression, (e) gaze, (f) a human voice, (g) personalized speech, and (h) interactive behavior by reacting to a learner's actions (e.g., providing verbal feedback). This study investigated the impact of an animated agent and the type of corrective feedback on learning, motivation and cognition in a multimedia environment.

1.1. Social agency theory perspective

Social agency theory (Atkinson, Mayer, & Merrill, 2005; Mayer, Sobko, et al., 2003) is one of the theoretical frameworks that researchers use to investigate the effectiveness of animated pedagogical agents in multimedia learning environments. According to this theory, an animated agent that appears on a computer screen and provides learners with verbal and/or non-verbal learning cues has the potential to prime their social-interaction schema and involve the learner in social interaction. As a result, learners may be triggered to interact with

* Corresponding author. Tel.: +86 21 6223 3280; fax: +86 21 6223 3352.
E-mail addresses: ljlin@psy.ecnu.edu.cn, lijia.lin615@gmail.com (L. Lin).

0360-1315/$ – see front matter
http://dx.doi.org/10.1016/j.compedu.2013.04.017

the agent in a computer-based multimedia learning environment in much the same way they would interact with their peer, mentor or teacher in a classroom. Once learners perceive a computer-based instructional episode as a social event, they apply social rules—the conventions for human-to-human communication—when they are interacting with the computer (Reeves & Nass, 1996; Van der Meij, 2013). There are a number of social norms primed by the human–computer interaction—one of which is the *cooperation principle* (Grice, 1975). Grice proposed that a person who is listening to someone talk in a human-to-human communication scenario will assume that the speaker is making a concerted effort to clearly communicate by being informative, accurate, relevant, and concise. Therefore, the learner is potentially motivated in this situation to make sense of what is being presented to him/her and will be more likely to process the information deeply and achieve meaningful learning. In effect, they will be more motivated to select relevant information and integrate it with prior knowledge.

There is modest empirical evidence in the educational research literature supporting social agency theory as several studies have revealed positive learning effects of presenting an animated pedagogical agent in a multimedia environment. For instance, Atkinson (2002) conducted a study in which an animated parrot (Peedy) was used in a multimedia program to deliver worked-example instruction about proportion-word problems. He found that participants studying content with the agent that narrated the instruction performed significantly better on learning outcome measures than their counterparts studying the same content with narrated instruction but no agent. This finding indicated that the presence of the agent enhanced the learning effectiveness of the multimedia environment (i.e., image effect). Other studies (e.g., Dunsworth & Atkinson, 2007; Lester et al., 1997; Lusk & Atkinson, 2007; Moreno, Mayer, & Lester, 2000; Moreno, Mayer, Spires, & Lester, 2001; Yilmaz & Kılıç-Çakmak, 2012) also showed that the presence of an agent fostered learning in a multimedia environment. Kim and Ryu (2003) reviewed 28 studies and found a strong positive learning effect for visually presented agents that are utilized to deliver instruction. In addition, past research revealed the positive impact of agents' voices (e.g., personalized speech) and affective behaviors (e.g., facial expressions) on learners' affective states (e.g., motivation and interest) in multimedia environments (Atkinson et al., 2005; Baylor & Kim, 2005, 2009; Kim & Baylor, 2006; Kim, Baylor, & Shen, 2007). These findings provide further evidence of social-motivational aspects of agents. Additionally, Atkinson et al. (2005) found that learners who studied worked examples that were narrated by an agent with a human voice rated the agent's speech more positively and had better performance on transfer test questions than their peers who studied examples accompanied by the same agent with a computer voice. Therefore, learning, motivation and cognition should all be considered and investigated in multimedia environments, as these three factors are influenced by different instructional methods and media (Brünken, Plass, & Moreno, 2010; Moreno, 2010; Moreno & Mayer, 2007).

1.2. Cognitive load theory perspective

Cognitive load theory (CLT; Paas, Renkl, & Sweller, 2003; Schnotz & Kurschner, 2007; Sweller, 1994; Sweller, Ayres, & Kalyuga, 2011; Sweller, van Merrienboer, & Paas, 1998) provides another theoretical framework for researchers to explain their findings in agent-based learning environments. CLT is built around a multicomponent working memory model (Baddeley, 2007) that assumes humans process information via dual sensory channels—audio/verbal channel and visual/pictorial channel and consequently have a limited working memory capacity. During the learning process, learners must select relevant information from the two channels, organize it in working memory and integrate it with their prior knowledge. This process is essential for learning, as it facilitates schema construction and the transfer of information to long-term memory (Sweller, 2005). Learners experience cognitive load when their working memory capacity has been exceeded.

There are three sources of cognitive load—intrinsic load, extraneous load and germane load. Intrinsic load is due to the natural complexity of the learning content that results from the number of interacting elements (element interactivity) necessary to process the task (Sweller, 2005). More interactive elements increase the intrinsic load, the working memory load (Sweller, 2010) and the difficulty level of the task. Extraneous load is caused by ineffective instructional design and should be reduced to promote learning. Finally, germane load is caused by the necessary effortful processing that is required to facilitate schema acquisition. Regardless of the source, the underlying cause of cognitive load that taxes limited working memory resources is proposed to be element interactivity (Sweller, 2010). Sweller suggested that this notion may make it difficult to assess how much load is caused by the different sources but that overall cognitive load can be still be determined and there is "…no reason why the currently commonly used subjective ratings of task difficulty…cannot be used to determine changes in overall cognitive load" (p. 128).

The design of instruction, or the instructional format, has the potential to impact how learners interact with a learning environment and experience cognitive load. For example, it could be argued that a multimedia learning program designed with an animated agent has no effect or even negative effect on learning. According to Harp and Mayer (1998), an animated agent that displays gestures, gaze, facial expressions or locomotion may provide learners too many seductive details and cause learners to split their attention from relevant information and consequently experience extraneous load (or additional element interactivity) in the learning environment. Results revealed from several studies (Chen, 2012; Choi & Clark, 2006; Craig et al., 2002; Mayer, Dow, & Mayer, 2003) support this claim. For instance, in Choi and Clark's study (2006), either an animated agent or an arrow was used in a multimedia program to teach an English language topic about relative clauses. However, the study failed to reveal any learning benefits for those who learned from the animated pedagogical agent. This finding is consistent with Mayer's (Mayer, Dow, et al., 2003) results, who found that participants who studied with an animated agent did not significantly improve on the transfer test compared to their peers who learned without an agent.

Irrespective of theoretical orientation, the current education research literature on the effectiveness of animated agents is rich with diverse research hypotheses and varied empirical outcomes (for review, see Heidig & Clarebout, 2011). In fact, some researchers have concluded that no generalization can be made about whether it is advantageous to embed an agent in a learning environment. Instead, research should investigate the specific conditions under which an agent enhances learning by taking into account a series of potential moderators, such as learner characteristics, the agent's functions, the agent's design, learning environments, and the type of knowledge (Atkinson et al., 2009; Johnson, DiDonato, & Reisslein, 2013; Kim & Wei, 2011; Ozogul, Johnson, Atkinson, & Reisslein, 2013; for review, see Dehn & van Mulken, 2000; Heidig & Clarebout, 2011). Therefore, they recommended that empirical research should address the effect of a specific type of agent in a specific domain. In order to shed light on the mixed and inconclusive empirical results on animated pedagogical agents, the current study was designed to investigate the learning and motivational benefits of an animated agent that functioned to provide verbal feedback in a multimedia environment designed to deliver science instruction.

1.3. Types of verbal feedback

Shute (2008) defined feedback as "information communicated to the learner that is intended to modify his or her thinking or behavior for the purpose of improving learning" (p. 154). Instructional designers considered feedback as one of the important elements of effective instruction (Sullivan & Higgins, 1983), as it has the potential to assist learners monitor their own learning (Butler & Winne, 1995). In the past several decades, researchers have investigated the role of feedback in learning and instruction from multiple perspectives, e.g., the timing of feedback (immediate feedback vs. delayed feedback, Schroth, 1992), the source of feedback (self-generated feedback vs. externally provided feedback, Andre & Thieman, 1988) and the degree of elaboration of feedback (simple feedback vs. elaborate feedback, Moreno, 2004). To help researchers and practitioners better understand the effectiveness of feedback, a couple of models of feedback were proposed from review articles (Bangert-Drowns, Kulik, Kulic & Morgan, 1991; Butler & Winne, 1995; Hattie & Timperley, 2007). The commonality of these models is that the effectiveness of feedback is related to a range of factors internal (e.g., meta-cognition) and external (e.g., task level) to learners. This is supported by the results of a meta-analysis conducted by Azevedo and Bernard (1995), which revealed that the effect of a particular type of feedback was inconsistent in the literature.

One category distinguishes feedback into simple and elaborate feedback based on the amount of information contained in the feedback (Bangert-Drowns et al., 1991). Feedback can be as simple as a confirmation of whether a learner's response is correct or not (simple feedback) or it can provide an explanation for correct and incorrect responses (elaborate feedback). In a review of 40 research studies utilizing either computerized or non-computerized environments, Bangert-Drowns et al. (1991) found that results from studies that used elaborate feedback produced larger effect sizes compared to results from studies that used simple feedback. Additionally, studies that utilized computer-based learning environments also revealed results that showed the effectiveness of elaborate feedback (e.g., Narciss & Huth, 2006; Pridemore & Klein, 1991). For instance, Pridemore and Klein (1991) found that participants who received elaborate feedback outperformed their counterparts who received verification feedback (i.e., simple feedback), regardless of whether learner control was provided. One interpretation of this effect is that elaborate feedback cues the learners into a cognitive elaboration process, which enhances deep understanding (Anderson & Reder, 1979).

One of the affordances of an animated pedagogical agent is its ability to serve as a source of verbal social cues (e.g., feedback) when learners are interacting with the multimedia environment. Considering that the feedback is most effective when it fosters cognitive processes (Azevedo & Bernard, 1995; Bangert-Drowns et al., 1991), it is possible and plausible to predict that providing verbal feedback that is external to learners, facilitates positive learning outcomes in the agent-based environments. For instance, participants in two studies (Moreno, 2004; Moreno & Mayer, 2005) completed an activity designing plants for various weather conditions in a discovery game-like learning environment augmented with an animated agent (called Herman the Bug). The results of both studies revealed that spoken explanatory feedback (i.e., elaborate feedback) provided by the agent promoted learning and reduced perceived cognitive load more effectively than when the same agent provided simple feedback. However, as the review of past literature revealed a wide range of variables that influence the effectiveness of feedback, it is worthwhile continuing to investigate the interplay between the agent and feedback by extending previous studies by Moreno and her colleagues (Moreno, 2004; Moreno & Mayer, 2005) by using a non-gaming environment and incorporating a no agent control group to deliver different types of feedback.

2. Overview of experiment

The purpose of the current study was to investigate the effects of an animated pedagogical agent that provided verbal feedback in a multimedia learning environment. Specifically, the study was designed to test the social agency theory and the cognitive load theory by exploring the effect of the agent (agent or no-agent) and type of feedback (simple or elaborate), as well as the potential interaction between the agent and the type of feedback, on a learning outcome measure and perceived motivation and cognitive load ratings. The study addressed three research questions within a multimedia learning environment: (a) How does the presence of an animated agent that narrates instructional content impact learning, motivation and cognitive load? (b) How does the type of instructional feedback affect learning, motivation and cognitive load? and, (c) How does the presence of the agent interact with the type of feedback with respect to learning, motivation and cognitive load?

Two independent variables were manipulated in the study—the presence of an agent (agent or no agent) and the type of verbal feedback (simple or elaborate). The dependent variables were participants' (a) learning outcomes, (b) subjective ratings of cognitive load, and (c) subject ratings of motivation. Learning time was also included as an en-route variable.

Because of the mixed results in the literature (e.g., Dehn & van Mulken, 2000; Heidig & Clarebout, 2011) regarding the effect of animated agents on learning, we tested hypotheses according to the social agency theory perspective as well as the cognitive load theory perspective. We hypothesized that participants in the agent conditions would perform better on a learning outcome measure and report higher levels of intrinsic motivation. The social agency theory supports this hypothesis and the assertion that agents have the capacity to evoke a learner's social schema and promote motivation to select and process relevant learning stimuli. However, from the cognitive load theory perspective, we hypothesized that the presence of the agent would—at a minimum—have no impact on learning compared to the no agent conditions and might even contribute to higher levels of perceived cognitive load. Thus, we hypothesized that the participants provided with an agent would report higher levels of extraneous cognitive load.

In terms of feedback, we had several hypotheses. We hypothesized that participants who learned with elaborate feedback would perform better on a learning outcome measure given that elaborate feedback provides instructional explanation while simple feedback does not. Finally, we hypothesized from a social agency theory perspective that participants who learned with an agent providing elaborate feedback would outperform their peers learning from an agent providing simple feedback on the learning outcome measure. This hypothesis also takes into account the impact of potential moderating variables (Azevedo & Bernard, 1995; Dehn & van Mulken, 2000; Heidig & Clarebout, 2011).

3. Method

3.1. Participants and design

The participants consisted of 135 undergraduate and graduate students from a southwestern university in the US. They were recruited from a participant pool, as well as from flyers and emails that were distributed throughout campus. A wide range of disciplines (Education, Engineering, Music, Business, Journalism, etc), representing the general student population, participated in the study. Participants were either paid a small stipend ($20) or received class credits for participation. The sample was comprised of 55 (41%) males and 80 (59%) females. The average age of the participants was 26.01 ($SD = 9.21$).

This study used a pretest–posttest, 2×2 factorial design; the first factor was the agent presence (animated agent with narration vs. narration only) and the second factor was the type of verbal feedback (simple feedback vs. elaborate feedback). Participants were randomly assigned to one of the four conditions: (a) Agent/Simple (an animated agent narrating the content and providing simple feedback), (b) Agent/Elaborate (an animated agent narrating the content and providing elaborate feedback), (c) No-agent/Simple (content and simple feedback were presented with narration alone), and (d) No-agent/Elaborate (content and elaborate feedback were presented with narration alone).

3.2. Computer-based multimedia learning environment

The computer-based materials were composed of a multimedia learning environment that contained three lessons about thermodynamics—Lesson 1: Introduction to Thermal Energy Transfer, Lesson 2: Thermal Energy Transfer by Conduction, and Lesson 3: Thermal Energy Transfer by Convection. The learning environment consisted of 23 screens and was created in Visual Basic and embedded with animated movies created in Adobe Flash. In each of the four experimental conditions, participants viewed the same number of screens (i.e., 23) embedded with animations about thermodynamics. There were no time constraints imposed on learners and thus the degree of learner control was consistent across all four conditions. There were a total of 12 multiple-choice practice questions (four in Lesson 1, three in Lesson 2 and five in Lesson 3) dispersed among the content screens. Practice was included in the design of the learning environment as it is an essential component of effective instruction, its inclusion helps to emulate an authentic learning environment and it was the activity for which feedback was provided.

Each condition differed with regard to the presence of the agent and the type of verbal feedback that learners received when they responded to the practice questions. In the Agent/Simple condition, a female human agent (head and shoulders shot) appeared on each screen, narrated the instructional content (see Fig. 1) and provided simple feedback verifying right or wrong each time after the participant responded to a multiple-choice practice question (see Fig. 2). The participant would receive the statement “Yes, that’s correct” when correctly answering the practice question, or receive the statement “No, that’s wrong” when incorrectly answering the practice question. In Agent/Elaborate condition, the same agent, positioned at the same location on the screen as the agent in the Agent/Simple condition, delivered auditory instruction and provided elaborate feedback on each of the participant’s responses to the practice questions. The extent of the agent’s non-verbal social cues was controlled for in the two agent conditions. Specifically, the agent’s facial expression, voice, clothing

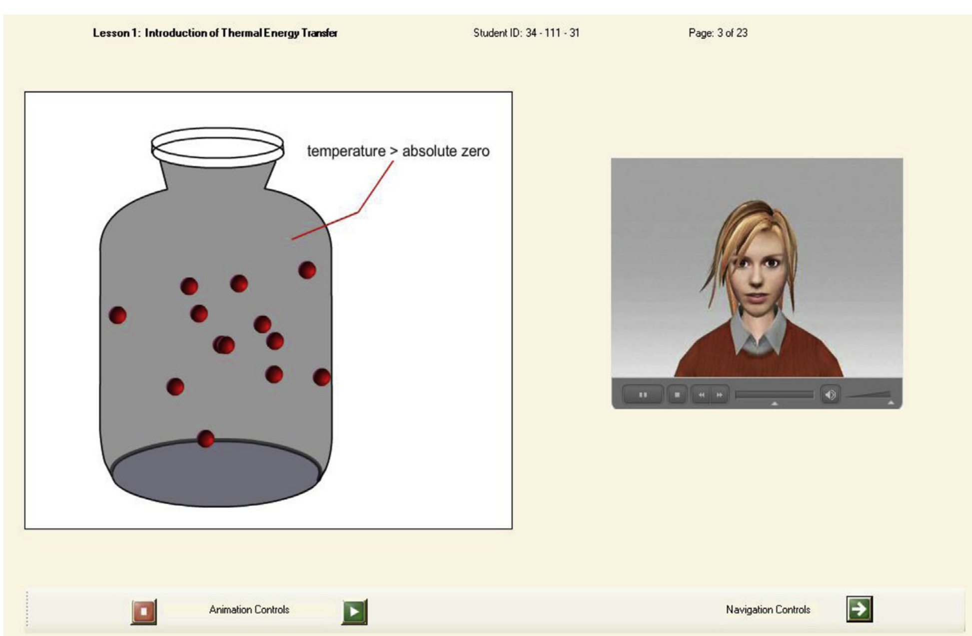

Fig. 1. Agent narrating the content.

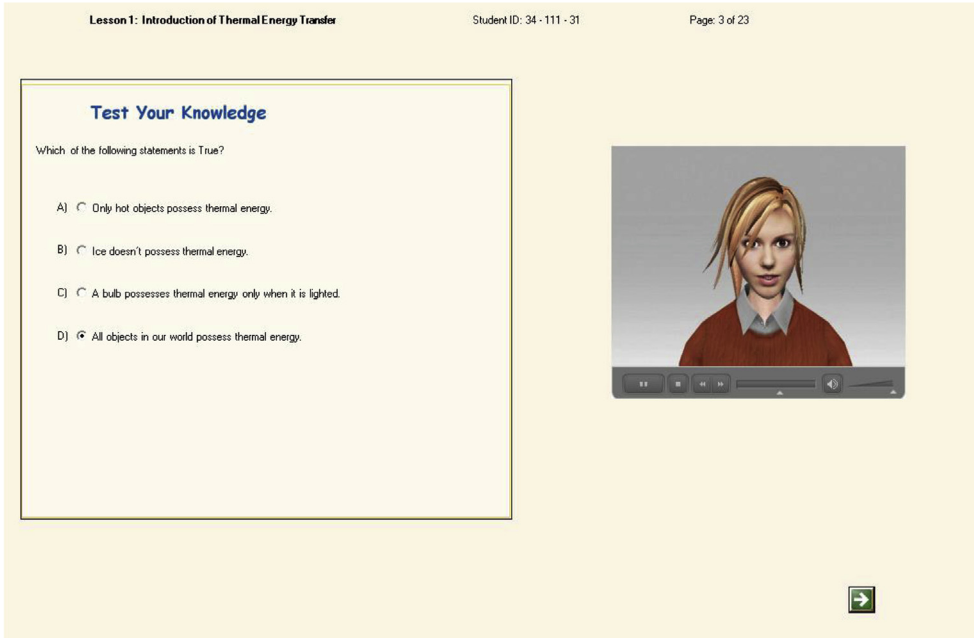

Fig. 2. Agent providing the feedback.

and the degree and timing of the head movement were exactly the same in Agent/Simple condition and Agent/Elaborate condition. The elaborate feedback in Agent/Elaborate condition not only included verification of right or wrong, but also included information as to why the answer was right or wrong. An example of this type of feedback was "Your answer is wrong because temperature is a measure of the average kinetic energy of the particles in a substance, not a process of energy transfer." Within the computer-based learning environment, the interface for the No-agent/Simple condition and No-agent/Elaborate condition were almost identical to the conditions with the agent present, except that the participants could not view the agent and only heard the narrated learning content (see Fig. 3) and feedback during the practice activity (see Fig. 4). Although the presence of the agent differed across the four conditions (agent and no agent), the audio narrations were the exactly the same.

A tutorial screen (Fig. 5) was launched by the computer program before the instruction started. The purpose of providing participants with a tutorial screen was to explain the controls of navigation and animation of the learning environment. No content-related graphics, narration or agent appeared on the screen.

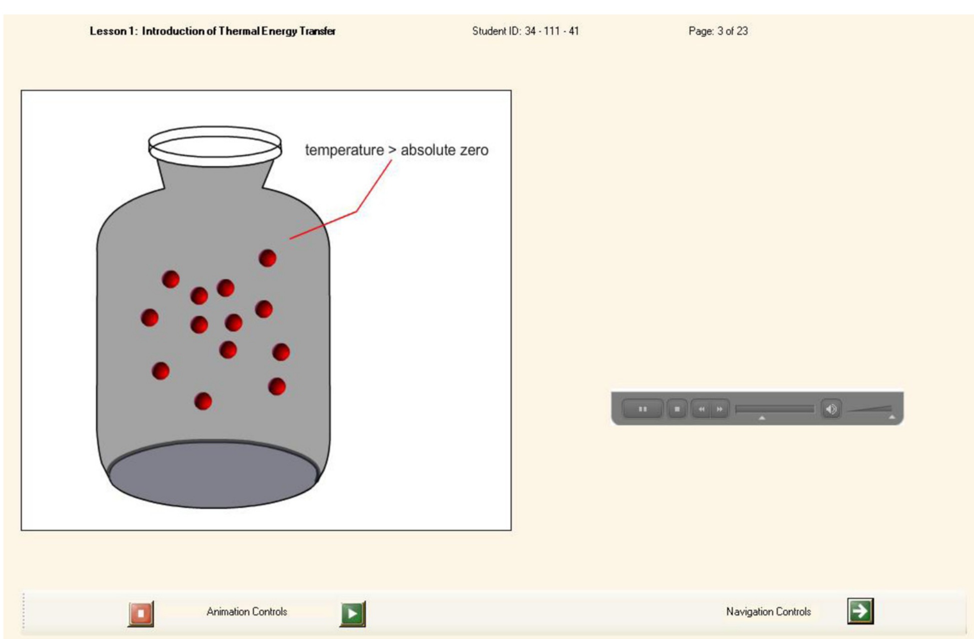

Fig. 3. No agent (narration only) delivering the content.

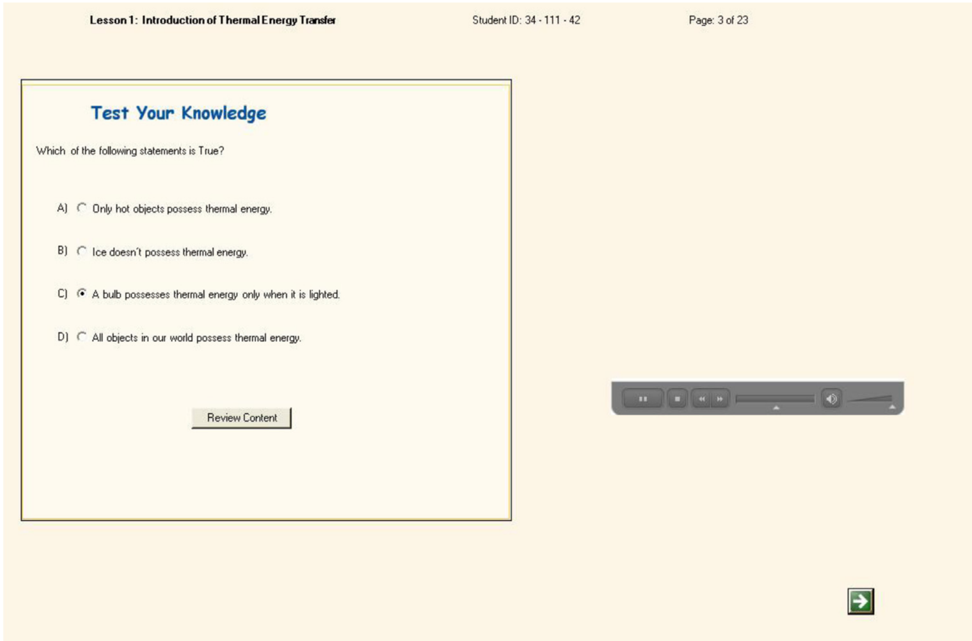

Fig. 4. No agent (narration only) providing the feedback.

3.3. Measures and instruments

Participants' prior knowledge about the learning content—thermodynamics—was measured by a pretest of 20 multiple-choice questions. Each test question had four choices—one correct answer and three distracters. A participant received zero points for each incorrect answer and one point for each correct answer. Therefore, a maximum of 20 points could be achieved. Participants' performance on the pretest was automatically scored by the computer-based program. A posttest was administered immediately after the instruction to measure learning outcomes. The posttest was identical to the pretest but the items were reordered. It had the same format, the same number of test questions and the same scoring method as the pretest. In addition to the pretest and posttest, 12 multiple-choice practice questions, which had the same format and scoring method, were interspersed between screens of the content. Each practice question was related to the content of the screen or screens immediately preceding it and practice opportunities were similar for each content area included on the posttest.

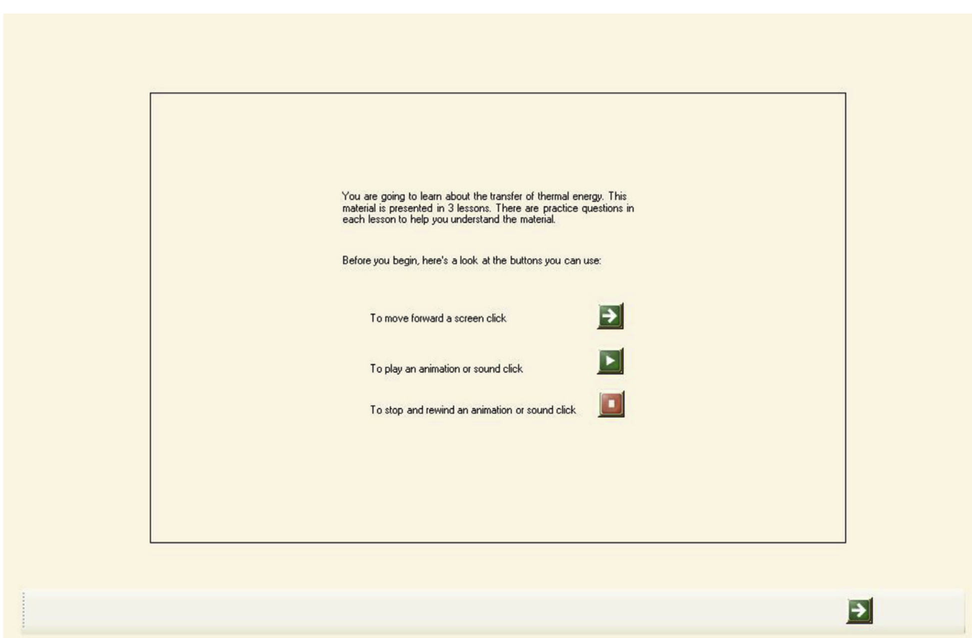

Fig. 5. Tutorial screen.

Table 1
Cognitive load measurement.

Item
1. How difficult was the lessons?
2. How much mental effort did it take to learn the lessons?
3. How hard was it to navigate through the lessons?
4. How frustrated were you during the lessons?

Four subjective questions were used to measure cognitive load (see Table 1). They were adapted from the NASA-TLX (Hart & Staveland, 1988) and were described by Gerjets, Scheiter and Catrambone (Gerjets, Scheiter, & Catrambone, 2004; Scheiter, Gerjets, & Catrambone, 2006). Each cognitive load question contained a Likert-type rating scale from 1 (very low cognitive load) to 8 (very high cognitive load). The focus of the questions was to measure participants' perception of task difficulty as this is the aspect of cognitive load that reflects element interactivity and is an indicator of overall cognitive load (Sweller, 2010). An item specifically assessing perception of task difficulty was used along with three additional items related to cognitive load: perception of effort, ease of task, and frustration. The use of the additional items was exploratory and a factor analysis was conducted to determine the factor structure for each of the items as they related to the construct of cognitive load.

There were 15 statements used to measure participants' intrinsic motivation, which was adapted from McAuley, Duncan, and Tammen (1989) and Ryan (1982). This intrinsic motivation scale included six subscales—interest, competence, value, effort, pressure and choice (see Table 2). Participants ranked each item on an 8-point Likert scale ranging from 1 ("not at all true") to 8 ("very true"). Negatively worded items were reverse-scored such that higher scores reflect more positive motivation.

3.4. Procedure

The experiment was conducted in a controlled multimedia laboratory setting. First, participants signed a consent form to participate and were then seated at an individual cubicle, facing a computer monitor. Next, a researcher informed participants about the goal and procedure of the experiment. However, participants were left unaware of the experimental conditions and the research questions. Then, they completed the pretest on the computer with no time limit and were randomly assigned to a condition with an experiment ID number. Experiment ID numbers were used to preserve the anonymity of each participant. When the participants completed the lesson, a posttest and a questionnaire were administered, both of which did not have a time limit. When these items were completed, participants were thanked and either paid or provided course credit. The study was approximately 60 min in duration.

4. Results

All participants' data were included in the analysis for two reasons: (a) there were no missing cases; and (b) the results of preliminary data screening showed no outliers. Table 3 presents the means and standard deviations (in parentheses) of participants' (a) total pretest scores, (b) total posttest scores, and (c) adjusted total posttest scores, where appropriate. Family-wise alpha was set at the .05 level. Cohen's f was used as an effect size measure with .10, .25 and .40 defined as small, medium and large effect sizes, respectively (Cohen, 1988).

4.1. Prior knowledge

An analysis of variance (ANOVA) was conducted to evaluate whether participants' prior knowledge significantly differed across the four experimental conditions (i.e., Agent/Simple, Agent/Elaborate, No-agent/Simple and No-agent/Elaborate). There was no significant main effect for the agent presence or the type of verbal feedback (both Fs < 1.00 and both ps $> .50$), nor was there a significant interaction effect, $F(1, 131) = 2.18$, $p = .14$.

Table 2
Intrinsic motivation items.

Item	Subscale
1. I thought it was a boring activity.	Interest
2. I think I was pretty good at this activity.	Competence
3. I think that doing this activity could be useful.	Value
4. I didn't try very hard to do well at this activity.	Effort
5. I did not feel nervous at all while doing this.	Pressure
6. I believe I had some choice about doing this activity.	Choice
7. It was important to me to do well at this task.	Effort
8. I believe doing this activity could be beneficial to me.	Value
9. I felt very tense while doing this activity.	Pressure
10. I did this activity because I had no choice.	Choice
11. This activity was fun to do.	Interest
12. I put a lot of effort into this.	Effort
13. This was an activity that I couldn't do very well.	Competence
14. I believe this activity could be of some value to me.	Value
15. I would describe this activity as very interesting.	Interest

Table 3
Mean and standard deviations of test scores.

	Agent						No Agent					
	Simple feedback ($n = 32$)			Elaborate feedback ($n = 34$)			Simple feedback ($n = 35$)			Elaborate feedback ($n = 34$)		
	M	*SD*	Adj. *M*	*M*	*SD*	Adj. *M*	*M*	*SD*	Adj. *M*	*M*	*SD*	Adj. *M*
Pretest	11.16	4.45		9.94	3.10		10.51	3.70		11.15	3.19	
Posttest	14.87	3.84	14.52	15.50	3.20	16.05	15.00	3.68	15.12	15.35	3.19	15.01
Difficulty	3.97	2.06		3.76	1.72		4.17	1.81		3.53	1.76	
Mental effort	3.91	1.91		4.12	1.74		4.31	2.13		3.53	1.83	
Navigation	1.69	1.49		1.62	1.13		1.63	1.06		1.65	.081	
Frustration	2.41	1.62		2.12	1.23		2.37	1.77		2.93	1.22	
Overall CL[a]	2.99	1.35		2.90	1.07		3.12	1.27		2.68	1.13	
Interest/IM[b]	5.94	1.16		6.09	1.25		6.10	1.59		6.34	1.20	
Competence/IM	5.67	1.33		6.01	1.27		5.83	1.25		6.01	1.41	
Value/IM	4.88	.95		5.17	1.05		4.95	1.35		4.83	1.10	
Effort/IM	5.55	1.23		5.54	1.22		5.57	1.13		5.91	1.17	
Pressure/IM	4.05	1.40		4.22	1.36		3.87	1.17		3.97	1.11	
Choice/IM	3.78	.90		3.97	.97		3.76	1.09		3.93	.75	
Time[c]	14.18	3.26		14.90	2.72		14.42	2.83		14.72	2.54	

Note. The maximum scores of both pretest and posttest were 20.
[a] Overall CL = Overall Cognitive Load.
[b] IM = Intrinsic Motivation.
[c] The unit of time is minute.

4.2. Learning outcomes

A two-way analysis of covariance (ANCOVA) was conducted. The first factor was agent presence with two levels, agent and no-agent; the second factor was type of feedback with two levels, elaborate and simple. The dependent measure was the score on the posttest and the covariate was the score on the pretest. An a priori analysis of the homogeneity-of-slopes assumption indicated that the relationship between the pretest score and the posttest score did not differ significantly as a function of the agent presence or the type of feedback (both Fs < 1.00). The ANCOVA showed a significant interaction, $F(1, 130) = 4.60$, $MSE = 4.88$, $p = .03$, $f = .19$ (see Fig. 6). However, the main effect for agent presence was not significant, $F(1, 130) = .34$, $MSE = 4.88$, $p = .56$, $f = .05$, and neither was the main effect for type of feedback, $F(1, 130) = 3.43$, $MSE = 4.88$, $p = .07$, $f = .16$.

To clarify the significant interaction effect, we conducted follow-up analyses of simple main effects controlling for the effect of pretest scores. We found that participants in the Agent/Elaborate condition ($Mean = 15.50$, $SD = 3.20$, adjusted $M = 16.05$) achieved higher posttest scores than their counterparts in the Agent/Simple condition ($Mean = 14.87$, $SD = 3.84$, adjusted $M = 14.52$), $F(1, 130) = 7.77$, $p = .006$, $f = .24$. All of the remaining analyses were non-significant (all Fs < 1.20 and all ps $> .28$).

4.3. Cognitive load

Four separate ANOVAs were conducted to evaluate the effects of agent and type of feedback on learners' perceived difficulty, mental effort, navigation of the environment and frustration respectively. There were no significant main effects or interaction effects (all Fs < 2.30 and all ps $> .13$).

In addition, a confirmatory factor analysis was conducted on the four cognitive load measures to determine whether the four measures assess a single underlying factor of cognitive load. The fit of the hypothesized single-factor model was assessed by the robust maximum

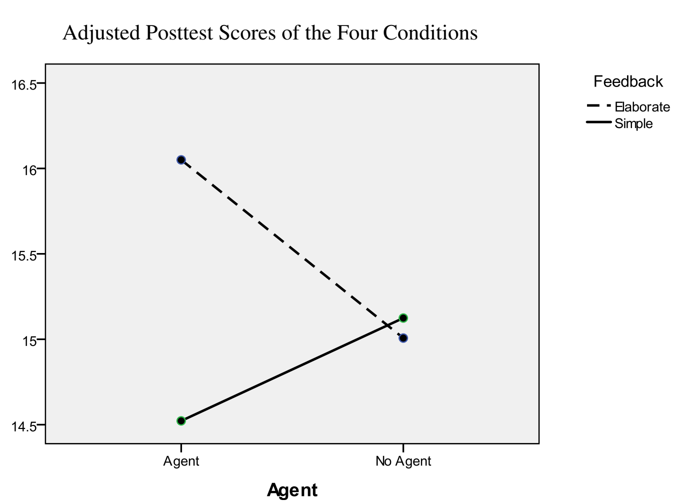

Fig. 6. Interaction effect on adjusted posttest scores.

likelihood estimation in Mplus 6.1. The results showed that the hypothesized model had an acceptable fit, $\chi^2(2) = 6.14$, $p = .047$, CFI = .97, SRMR = .05, RMSEA = .12, 90% CI [.01–.23]. Based on this empirical evidence, the mean of the four cognitive load measures was computed for each participant to represent the overall cognitive load. A two-way ANOVA was then conducted to assess the potential effect of agent and feedback on the overall cognitive load. However, there were no significant main effects or interaction (all Fs < 1.60 and all ps > .21).

4.4. Intrinsic motivation

Means of participants' ratings on each of the six subscales—interest, competence, value, effort, pressure and choice—of intrinsic motivation measures were computed. A two-way multivariate analysis of variance (MANOVA) was conducted to determine the effects of the agent presence and the type of verbal feedback on these six subscales. No significant differences were found on the six subscales for the agent presence main effect, Wilks' $\Lambda = .98$, $F(5, 127) = .48$, $p = .79$, $f = .14$, or for the type of verbal feedback main effect, Wilks' $\Lambda = .97$, $F(5, 127) = .85$, $p = .52$, $f = .18$. The interaction effect was also non-significant, Wilks' $\Lambda = .93$, $F(5, 127) = .96$, $p = .41$, $f = .20$.

4.5. Learning time

A two-way ANOVA was conducted to evaluate the effects of agent and the type of verbal feedback on the learning time (in minutes) spent by the participants in the multimedia environment. There was no main effect for agent, no main effect for the type of verbal feedback, and no interaction effect (all Fs < 1.09 and all ps > .30).

5. Discussion

The findings in the educational research literature regarding the effects of animated pedagogical agents (image effect) are varied and inconclusive. Results from some studies support the agent's image effect (e.g., Atkinson, 2002; Dunsworth & Atkinson, 2007; Lester et al., 1997) while others do not (e.g., Moreno et al., 2001). This study was designed to explore Dehn and van Mulken's (2000) recommendation to study a specific type of agent in a specific domain and attempt to disentangle the complex design issues involved in creating and delivering instruction via a pedagogical agent in a multimedia learning environment for college students. We investigated the learning, motivational, and cognitive benefits of utilizing an animated agent to provide two different types of verbal feedback during an instructional multimedia science module about thermodynamics.

5.1. How does the presence of an animated agent that narrates instructional content impact learning, motivation and cognitive load?

There were no significant main effects for the agent factor on learning outcome measures or for perceived motivation. Thus, there was no support for our hypothesis based on social agency theory that the presence of an agent would support learning and motivation. Instead, the finding that the participants who learned without the presence of the agent performed equivalent to participants provided with an agent on the learning measure provides partial support for our hypothesis based on cognitive load theory, i.e., the agent's presence would not foster learning. On the other hand, since cognitive load theory also suggests that the presence of an animated agent could be a source of cognitive load, it is also reasonable to anticipate that learners in the agent conditions would report higher levels of perceived cognitive load. However, this was not the case as participants experienced the agent and no-agent conditions similarly with regard to self-report measures of motivation and cognitive load as there were no significant mean differences among conditions. This finding provides evidence that participants did not necessarily experience the agent conditions with an increased level of cognitive load as indicated in the previous studies (Choi & Clark, 2006; Craig et al., 2002; Mayer, Dow, et al., 2003). We can postulate that the agent's presence in the learning environment did not appear to impose an additional amount of element interactivity that could be detected by the self-report measure. Participants in the agent conditions did not report significantly higher levels of perceived cognitive load despite the fact that our animated agent was programmed with head movement, gaze, and lip-synced narration. An alternate explanation is that our cognitive load measurement tool may not have been sufficiently sensitive to changes in perceived levels of cognitive load. Further research is needed to determine how best to measure cognitive load in multimedia environments.

5.2. How does the type of instructional feedback affect learning, motivation and cognitive load?

Likewise, there were no significant main effects for the type of feedback on the learning outcome measure, and consequently, we did not find support for our hypothesis that participants would perform better when provided with elaborate rather than simple feedback. While we did not find a statistically significant difference, the descriptive statistics suggested an advantage for the elaborate feedback condition given the estimated effect size ($f = .16$) and that the difference approached significance ($p = .07$). While we cannot definitively state that the elaborate feedback fostered learning to a greater degree than simple feedback, our descriptive statistics are consistent with previous findings documenting the advantage of elaborate feedback. As mentioned previously, we did not find any significant main effect for the feedback factor on the measures of intrinsic motivation instrument or cognitive load.

There are various perspectives to distinguish different feedback (Bangert-Drowns et al., 1991). In this study, we investigated the type of feedback in an agent-based learning environment, in which an animated agent provided verbal feedback with different amount of information, i.e., simple feedback and elaborate feedback. Other types of feedback, such as the feedback modality (text vs. audio), may also impact learning outcomes, motivation and cognitive load in the agent-based environment. Future research should further investigate these interesting issues.

5.3. How does the presence of the agent interact with the type of feedback with respect to learning, motivation and cognitive load?

We did find a significant interaction between the presence of an agent and the type of feedback it provided during learning. Our results indicated that learners benefited the most from the animated agent that provided elaborate verbal feedback relative to an agent that provided simple feedback. This finding is consistent with social agency theory as there is an indication that the agent giving elaborate feedback potentially enriched the learning environment by providing a higher degree of social cues (Atkinson et al., 2005; Mayer, Sobko, et al., 2003). In other words, the animated pedagogical agent providing elaborate feedback is better able to evoke learners' social schema and thus facilitate deep processing and meaningful learning compared to the same agent providing simple feedback. This result, in combination with the findings that there were no main effects for agent or for type of feedback, contributes to the current literature by directly addressing the question "When is a pedagogical agent effective?" The result supports the notion that the effectiveness of an agent in a multimedia environment depends on the type of feedback a pedagogical agent delivers, one of the functions that an agent executes (Heidig & Clarebout, 2011). However, it is unclear if the learning effect is a result of including an instructional manipulation, such as the provision of elaborate feedback, or a result of the agent "behaving" in a manner that was more consistent with learners' expectations of a mentor or teacher. Perhaps learners experienced the agent that offered elaborate feedback as a more authentic learning companion and therefore it was more effective at evoking learners' social schema and promoting them to adopt the cooperation principle in their interaction with the computer environment and learning process.

The findings in this study only partially support the agent's image effect in the multimedia environment on condition that the animated agent presents narrated elaborate feedback to learners' responses on the multiple-choice practice questions. This implicates that the learning benefits of incorporating an agent in the multimedia environment may not be applied to the general instructional settings, but to some specific settings where a human-like agent is designed to provide maximum verbal social cues, such as elaborate feedback provided by a visually presented agent. Instructional design and development of the agent-based learning environments should not only take into account the technological aspects of the animated agent, but also the cognitive aspects of the agent or the computer-based learning environment. In future research, we will further investigate the moderating effect of the type of feedback in an agent-based learning environment. For instance, we can consider manipulating the presence of an animated agent either in the content delivery phase or in the practice activity providing different types of feedback so that we can clearly investigate the potential moderating effect of different types of feedback.

The current study provides evidence that learning is fostered when an animated agent provides learners instructional explanations (i.e., elaborate feedback) via human narration after they respond to practice questions. It is possible learners are prompted by the agent's social cues, especially the elaborate verbal feedback, to self-explain what they have learned and, in turn, this possible self-explanation process leads to better learning and understanding (Chi, de Leeuw, Chiu, & LaVancher, 1994). However, the current study did not collect any self-explanation data, which limits our ability to attribute the learning effects to this type of process. In future research, we will consider using methods to collect data of learners' self-explanation, such as think aloud method or written self-explanations. By doing so, we could have a clearer idea of learners' inner mechanism in a multimedia environment augmented with an animated agent.

We need to note that the animated agent used in the current study is a human female character coupled with human female voice recordings. The study conducted by Lattner, Meyer, and Friederici (2005) indicated that learners preferred a female voice to a male voice, whereas Harrison and Atkinson (2009) found no impact of the agent's gender on learning. Thus, it is possible that an animated pedagogical agent's gender may have differential impacts on learners. Moreover, an agent's degree of anthropomorphism may impact its effectiveness in supporting learning. In future research, we intended to investigate whether we see the same interaction effect between agent and feedback when a human male character or a non-human cartoon character provides elaborate verbal feedback.

We also found that learners spent equivalent amount of time learning the content in the environment, regardless of the type of feedback provided or the presence/absence of the agent. Taking into account that there was no substantial difference of learning times across the four conditions, we can conclude that it is not the amount of instructional explanations included in the feedback but the function of an agent that provides feedback that impact on learning in the multimedia environment. The current findings suggest that elaborate verbal feedback has the potential to promote learning in the agent-based environment when social cues are maximally provided—the presence of an animated agent plus verbal narration. Additionally, it is worth noting that participants presented with an agent that provided simple narration performed descriptively lower on the learning measure than their counterparts in the two non-agent conditions (no-agent plus simple feedback, no-agent plus elaborate feedback). This suggests that when the agent in our study provided simple feedback it was a detriment to learning. If we consider this finding in light of both the social agency theory and cognitive load theory, perhaps when an agent does not behave as a learner expects (offering useful explanations to promote learning), learners experience are less likely to adopt the cooperation principle, thereby limiting the degree to which they immerse themselves into the computer-based environment and learning process.

6. Conclusion

The results of the study indicate that an animated agent's ability to foster learning when deployed in a computer-based multimedia learning environment is moderated by instructional components, specifically the type of verbal feedback that an agent delivers. This study supports the idea that different types of verbal feedback may moderate the effect of the presence of an animated agent (image effect). It also suggests that when a computer-based multimedia learning environment is complemented by an animated agent for college students to obtain knowledge or skills in a certain domain, instructional designers should consider incorporating an agent that can optimally provide verbal social cues, such as elaborate feedback.

References

Anderson, J. R., & Reder, L. M. (1979). An elaborative processing explanation of depth of processing. In L. S. Cermak, & F. I. M. Craik (Eds.), *Levels of processing in human memory*). Hillsdale, NJ: Erlbaum.

Andre, T., & Thieman, A. (1988). Level of adjunct question, type of feedback, and learning concepts by reading. *Contemporary Educational Psychology, 13*, 296–307.

Atkinson, R. K. (2002). Optimizing learning from examples using animated pedagogical agents. *Journal of Educational Psychology, 94*(2), 416–427.

Atkinson, R. K., Foshee, C., Harrison, C., Lin, L., Joseph, S., & Christopherson, R. (2009). Does the type and degree of animation present in a visual representation accompanying narration in a multimedia environment impact learning?. In *Proceedings of world conference on educational multimedia, hypermedia and telecommunications 2009* (pp. 726–734) Chesapeake, VA: AACE.

Atkinson, R. K., Mayer, R. E., & Merrill, M. M. (2005). Fostering social agency in multimedia learning: examining the impact of an animated agent's voice. *Contemporary Educational Psychology, 30*(1), 117–139.
Azevedo, R., & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research, 13*(2), 111–127.
Baddeley, A. (2007). *Working memory, thought, and action*. New York, NY: Oxford University Press.
Bangert-Drowns, R. L., Kulik, C. C., Kulik, J. A., & Morgan, M. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research, 61*(2), 213–238.
Baylor, A. L., & Kim, Y. (2005). Simulating instructional roles through pedagogical agents. *International Journal of Artificial Intelligence in Education, 15*, 95–115.
Baylor, A. L., & Kim, Y. (2009). Designing nonverbal communication for pedagogical agents: when less is more. *Computers in Human Behavior, 25*(2), 450–457.
Brünken, R., Plass, J. L., & Moreno, R. (2010). Current issues and open questions in cognitive load research. In J. L. Plass, R. Moreno, & R. Brünken (Eds.), *Cognitive load theory* (pp. 253–272). New York, NY, US: Cambridge University Press.
Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: a theoretical synthesis. *Review of Educational Research, 65*(3), 245–281.
Chen, Z. H. (2012). We care about you: incorporating pet characteristics with educational agents through reciprocal caring approach. *Computers & Education, 59*, 1081–1088.
Chi, M. T. H., de Leeuw, N., Chiu, M., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science: A Multidisciplinary Journal, 18*(3), 439–477.
Choi, S., & Clark, R. E. (2006). Cognitive and affective benefits of an animated pedagogical agent for learning English as a second language. *Journal of Educational Computing Research, 34*(4), 441–466.
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J.: L. Erlbaum Associates.
Craig, S. D., Gholson, B., & Driscoll, D. M. (2002). Animated pedagogical agents in multimedia educational environments: effects of agent properties, picture features and redundancy. *Journal of Educational Psychology, 94*(2), 428–434.
Dehn, D. M., & van Mulken, S. (2000). The impact of animated interface agents: a review of empirical research. *International Journal of Human-Computer Studies, 52*(1), 1–22.
Dunsworth, Q., & Atkinson, R. K. (2007). Fostering multimedia learning of science: exploring the role of an animated agent's image. *Computers & Education, 49*(3), 677–690.
Gerjets, P., Scheiter, K., & Catrambone, R. (2004). Designing instructional examples to reduce intrinsic cognitive load: molar versus modular presentation of solution procedures. *Instructional Science, 32*(1–2), 33–58.
Grice, H. P. (1975). Logic and conversation. In P. Cole, & J. Morgan (Eds.). *Syntax and semantics*, Vol. 3, (pp. 41–58). New York: Academic Press.
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.
Harrison, C., & Atkinson, R. K. (2009). Narration in multimedia learning environments: exploring the impact of voice origin, gender, and presentation mode. In G. Siemens, & C. Fulford (Eds.), *Proceedings of world Conference on educational multimedia, hypermedia and telecommunications 2009* (pp. 980–985). Chesapeake, VA: AACE.
Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): results of experimental and theoretical research. In P. A. Hancock, & N. Meshkati (Eds.), *Human mental workload* (pp. 139–183). Amsterdam: North-Holland.
Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*, 81–112.
Heidig, S., & Clarebout, H. (2011). Do pedagogical agents make a difference to student motivation and learning? *Educational Research Review, 6*, 27–54.
Johnson, A. M., DiDonato, M. D., & Reisslein, M. (2013). Animated agents in K-12 engineering outreach: preferred agent characteristics across age levels. *Computers in Human Behavior, 29*, 1807–1815.
Kim, Y., & Baylor, A. L. (2006). A social-cognitive framework for pedagogical agents as learning companions. *Educational Technology Research and Development, 54*, 569–590.
Kim, Y., Baylor, A. L., & Shen, E. (2007). Pedagogical agents as learning companions: the impact of agent emotion and gender. *Journal of Computer Assisted Learning, 23*, 220–234.
Kim, M., & Ryu, J. (2003). Meta-analysis of the effectiveness of pedagogical agent. In D. Lassner, & C. McNaught (Eds.), *Proceedings of world conference on educational multimedia, hypermedia and telecommunications 2003* (pp. 479–486). Chesapeake, VA: AACE.
Kim, Y., & Wei, Q. (2011). The impact of learner attributes and learner choice in an agent-based environment. *Computers & Education, 56*, 505–514.
Lattner, S., Meyer, M. E., & Friederici, A. D. (2005). Voice perception: sex, pitch, and the right hemisphere. *Human Brain Mapping, 24*(1), 11–20.
Lester, J. C., Converse, S. A., Kahler, S. E., Barlow, S. T., Stone, B. A., & Bhoga, R. S. (1997). The personal effect: affective impact of animated pedagogical agents. In *Proceedings of CHI_97* (pp. 359–366). New York: ACM Press.
Lusk, M. M., & Atkinson, R. K. (2007). Animated pedagogical agents: does their degree of embodiment impact learning from static or animated work examples? *Applied Cognitive Psychology, 21*(6), 747–764.
McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: a confirmatory factor analysis. *Research Quarterly for Exercise and Sport, 60*, 48–58.
Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 31–48). New York, NY, US: Cambridge University Press.
Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia learning in an interactive self-explaining environment: what works in the design of agent-based microworlds? *Journal of Educational Psychology, 95*(4), 806–812.
Mayer, R. E., Sobko, K., & Mautone, P. D. (2003). Social cues in multimedia learning: role of speaker's voice. *Journal of Educational Psychology, 95*(2), 419–425.
Moreno, R. (2004). Decreasing cognitive load for novice students: effects of explanatory versus corrective feedback in discovery-based multimedia. *Instructional Science, 32*(1), 99–113.
Moreno, R. (2007). Optimizing learning from animations by minimizing cognitive load: cognitive and affective consequences of signaling and segmentation methods. *Applied Cognitive Psychology, 21*, 1–17.
Moreno, R. (2010). Cognitive load theory: more food for thought. *Instructional Science, 38*(2), 135–141.
Moreno, R., & Mayer, R. E. (2005). Role of guidance, reflection, and interactivity in an agent-based multimedia game. *Journal of Educational Psychology, 97*(1), 117–128.
Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19*(3), 309–326.
Moreno, R., Mayer, R., & Lester, J. (2000). Life-like pedagogical agents in constructivist multimedia environments: cognitive consequences of their interaction. In J. Bourdeau, & R. Heller (Eds.), *Proceedings of world conference on educational multimedia, hypermedia and telecommunications 2000* (pp. 776–781). Chesapeake, VA: AACE.
Moreno, R., Mayer, R. E., Spires, H. A., & Lester, J. C. (2001). The case for social agency in computer-based teaching: do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction, 19*(2), 177–213.
Narciss, S., & Huth, K. (2006). Fostering achievement and motivation with bug-related tutoring feedback in a computer-based training for written subtraction. *Learning and Instruction, 16*(4), 310–322.
Ozogul, G., Johnson, A. M., Atkinson, R. K., & Reisslein, M. (2013). Investigating the impact of pedagogical agent gender matching and learner choice on learning outcomes and perceptions. *Computers & Education, 67*, 36–50.
Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: recent developments. *Educational Psychologist, 38*(1), 1–4.
Pridemore, D. R., & Klein, J. D. (1991). Control of feedback in computer-assisted instruction. *Educational Technology Research and Development, 39*(4), 27–33.
Reeves, B., & Nass, C. (1996). *The media equation*. New York: Cambridge University Press.
Ryan, R. M. (1982). Control and information in the intrapersonal sphere: an extension of cognitive evaluation theory. *Journal of Personality and Social Psychology, 43*, 450–461.
Scheiter, K., Gerjets, P., & Catrambone, R. (2006). Making the abstract concrete: visualizing mathematical solution procedures. *Computers in Human Behavior, 22*, 9–25.
Schnotz, W., & Kurschner, C. (2007). A reconsideration of cognitive load theory. *Educational Psychology Review, 19*(4), 469–508.
Schroth, M. L. (1992). The effects of delay of feedback on a delayed concept formation transfer task. *Contemporary Educational Psychology, 17*, 78–82.
Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78*(1), 153–189.
Sullivan, H., & Higgins, N. (1983). *Teaching for competence*. New York, US: Teachers College Press.
Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*(4), 295–312.
Sweller, J. (2005). Implications for cognitive load in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 19–30). New York, NY: Cambridge University Press.
Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review, 22*, 123–138.
Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer.
Sweller, J., van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251–296.
Van der Meij, H. (2013). Motivating agents in software tutorials. *Computers in Human Behavior, 29*, 845–857.
Yilmaz, R., & Kılıç-Çakmak, E. (2012). Educational interface agents as social models to influence learner achievement, attitude and retention of learning. *Computers & Education, 59*, 828–838.