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Designing nonverbal communication for pedagogical agents: When less is more

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ABSTRACT

This experimental study employed a 2 × 2 × 2 factorial design to investigate the effects of type of instruction (procedural module, attitudinal module), deictic gesture (presence, absence), and facial expression (presence, absence) on student perception of pedagogical agent persona, attitude toward the content, and learning. The interaction effect between type of instruction and agent nonverbal behavior (deictic gestures and facial expression) was also investigated. A total of 236 college students learned from an animated pedagogical agent that varied by two factors: deictic gestures and facial expression within one of two instructional environments: one training them to perform tasks within a software program (procedural learning outcome); the other focusing on changing their beliefs regarding intellectual property (attitudinal learning outcome). Results indicated that the main effects of agent facial expression and gesture as well as the interaction were significant for agent perception and learning. With regard to learning, for attitudinal instruction, participants learned more when the agent's facial expression was present but deictic gesture was absent; however, for procedural instruction, students learned more when the agent's gestures were present. These results are discussed in light of a preliminary pedagogical agent design principle that suggests that it is most desirable to employ the one nonverbal communicative behavior that is most appropriate to the learning outcome.

1. Introduction

Research on animated pedagogical agents has examined the effects on a variety of learning-related outcomes, including learning transfer (Atkinson, 2002; Moreno, Mayer, Spires, & Lester, 2001), metacognition (Baylor, 2002), and motivation (Baylor & Kim, 2003, 2005; Baylor, Shen, & Huang, 2003). While there is exciting potential for implementing advanced technologies to employ pedagogical agents as "virtual humans" (e.g., Allbeck & Badler, 2003; Kim, Baylor, & Reed, 2003; Lester, Towns, Callaway, Voerman, & Fitzgerald, 2000), there are many unanswered questions with respect to effective design, particularly for specific learning outcomes.

In general, a pedagogical agent is constituted of several media features (e.g., image, animation, message, voice, and interactivity). Empirical research has now substantiated that the interface *image* itself, i.e., the agent's appearance, can have a profound impact on learning outcomes, particularly motivational outcomes (see review, Baylor, 2005; Baylor & Plant, 2005; Rosenberg-Kima, Baylor, Plant, & Doerr, 2008). For example, simply manipulating agent gender, attractiveness, or ethnicity can significantly enhance learner confidence and beliefs. With respect to agent *message*, manipulating its motivational (Baylor, Shen, & Warren, 2004) or affective (Baylor, Warren, Park, Shen, & Perez, 2005) content can also dramatically impact learner beliefs and attributions. With more advanced intelligent tutoring and dialogue systems (Aimeur & Frasson, 1996; Anderson, Corbett, Koedinger, & Pelletier, 1995; Gertner & VanLehn, 2000; Graesser, VanLehn, Rose, Jordan, & Harter, 2001), interface agents such as AutoTutor (Graesser, Moreno, & Marineau, 2003) can serve on the "front end" to engage learners in a dialogue to highlight their misconceptions and encourage deeper reasoning. Thus, the agent message can cognitively support individualized learning.

A particularly salient affordance of pedagogical agents is their propensity for effective message *delivery*. Thus, as a social interface, pedagogical agents can deliver messages as a social communicator (e.g., through voice and animation). Further, such agents can enhance learners' perception of social presence (Heeter, 1995; Steuer, 1992), or the degree to which an individual feels someone is socially present and collaborating in the same space (McIssac & Gunawardena, 1996; Nam, Shu, & Chung, 2008). The learners' perception of social presence in a computer-based environment is an important

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indicator of their satisfaction as well as the quality of the instructional medium (Gunawardena, 1995; Mykota & Duncan, 2007; Newberry, 2001; Romiszowski & Mason, 2004). Pedagogical agents serve as a social interface, displaying social and affective cues that can trigger social reactions (Fogg, 2002) and social relationships (Kim & Baylor, 2006, 2007). Therefore, the sense of being with others can be enhanced by social interaction between learners and virtual agents.

This is particularly relevant for instruction; for example, consider the unique characteristics of a human teacher's delivery of instruction as compared to reading the information from a textbook. While research conclusively indicates that having a human (as opposed to a computer-generated) voice is preferable (Atkinson, Mayer, & Merrill, 2005; Baylor, Ryu, & Shen, 2003; Reeves & Nass, 1996), prescriptive guidelines for agent nonverbal communication are nonexistent. Researchers have speculated that *facial expression* (eye, eyebrow, and mouth movements) and *deictic gestures* (pointing with arms and hands) are particularly important for pedagogical agents (Atkinson, 2002; Johnson, Rickel, & Lester, 2000; Lester, Towns, Callaway, Voerman, & Fitzgerald, 2000) in promoting learning-related outcomes. In particular, gesture can reduce ambiguity by focusing the learners' attention, and facial expressions can reflect the agent's emotion, personality and emphasize aspects of the message. Other empirical studies (Baylor & Ryu, 2003; Baylor, Ryu, & Shen, 2003) have investigated the general effects of agent animation (i.e., nonverbal communication), but the generalizability of the results are limited given that animation was not operationalized at a specific enough level of detail.

The relationship between nonverbal communication and learning-related outcomes has not been empirically investigated. For example, perhaps deictic gestures are particularly facilitative for learning procedures where the learner must focus attention amongst competing distractions; or, perhaps facial expressions facilitate persuasion and add impact to the message. The question of what is the most effective instantiation of agents' nonverbal behavior (e.g., deictic gestures and/or facial expressions) for particular learning outcomes is currently unanswered.

This experimental study investigates the relationship between the type of instruction for different learning outcomes (attitudinal or procedural) and two types of nonverbal animations (deictic gestures and facial expressions). Gagné proposed that different instruction is required for different learning outcomes (Driscoll & Burner, 2005). Procedural learning requires learners to learn each step of the task one at a time to eventually build up to performing the entire task. According to the taxonomy of learning outcomes classified by Gagné, procedural learning outcomes fall into the category of intellectual skills (Gagné, 1985). In contrast, attitudinal learning outcomes belong to the affective domain, and consist of an acquired internal state that influences the choice of personal action toward some class of thing, persons, or events (Driscoll, 2000).

It is unclear as to what is the best instantiation of animated pedagogical agents for message delivery for these two learning outcomes. Some would suggest that by providing both facial expressions and deictic gestures, students may be distracted (Mousavi, Low, & Sweller, 1995). Others suggest that through employing both facial expression and deictic gestures, additional information is conveyed to promote learning (see Cassell, Sullivan, Prevost, & Churchill, 2000). Yet, others suggest that consistency of agent features is critical and a mismatch of realism (e.g., facial expressions without gestures or vice versa) would be detrimental (Lee & Nass, 2003). However, the overriding question of which animations best fit the instructional purpose (e.g., to address different learning outcomes) has yet to be addressed.

Thus, the purpose of this experimental study is to explore the effects of nonverbal communication on attitude toward the content, agent perceptions, and learning. The independent variables include type of instruction (attitudinal or procedural), deictic gestures (presence or absence), and facial expression (presence or absence). Of particular interest are the interaction effects between the type of instruction and the agent nonverbal communication.

2. Methods

2.1. Research design

This study employed a $2 \times 2 \times 2$ factorial design, with type of instruction (procedural, attitudinal), deictic gestures (presence, absence), and facial expressions (presence, absence) as the three factors. The participants were randomly assigned to one of eight conditions and participated as a required course activity with the opportunity to choose not to have their data included in the research study. Fig. 1 shows the research design and sample screen shots for each condition.

2.2. Participants

The participants in this study included 236 undergraduate students (32% male and 68% female) enrolled in a computer literacy course in a southeastern public university. The majority were sophomores or juniors and the age range was from 17 to 24 years. Participants' majors were diverse, including marketing, nursing, education, communication, interior design, music, political science, criminology, psychology, and so forth.

2.3. Instructional materials

Two different instructional modules were developed for this study. One instructional module was designed to teach a procedural learning outcome, while the other module was designed to teach an attitudinal learning outcome. The procedural instructional module and the attitudinal instructional module were devised to be equivalent with respect to rigor, time (approximately 20 min each), and implementation of deictic gestures and facial expressions. Both modules were designed according to the results of a task-content analysis. Subject matter experts who had been teaching and managing the course validated both instructional modules. Based on the result of the task-content analysis, agent scripts were constructed that incorporated both the agent's message and nonverbal animation. For each of the four permutations of the module (deictic gestures $\times$ facial expressions), the number and distribution of animations were held as constant as possible.

2.3.1. Procedural instructional module (PIM)

The purpose of the procedural instructional module was to teach the participants how to use a web-based software program designed to assess their proficiency in Microsoft Office© applications. Given that the focus was on procedural information, the module was designed with an organized and linear information structure (Gagné, 1985). Within the module, the pedagogical agent showed the participants how to perform specific tasks associated with using the web-based software application, e.g., navigating the interface.

2.3.2. Attitudinal instructional module (AIM)

The purpose of the attitudinal instructional module was to elicit more desirable attitudes in students towards intellectual property rules and laws. Given that the focus here was on attitudinal information, the module incorporated four realistic scenarios (Digital Music and Copyright Law; Electronic Plagiarism; Movie Recording with Camcorder and P2P Sharing; and Software Copying) that students might encounter in their daily lives related to intellectual

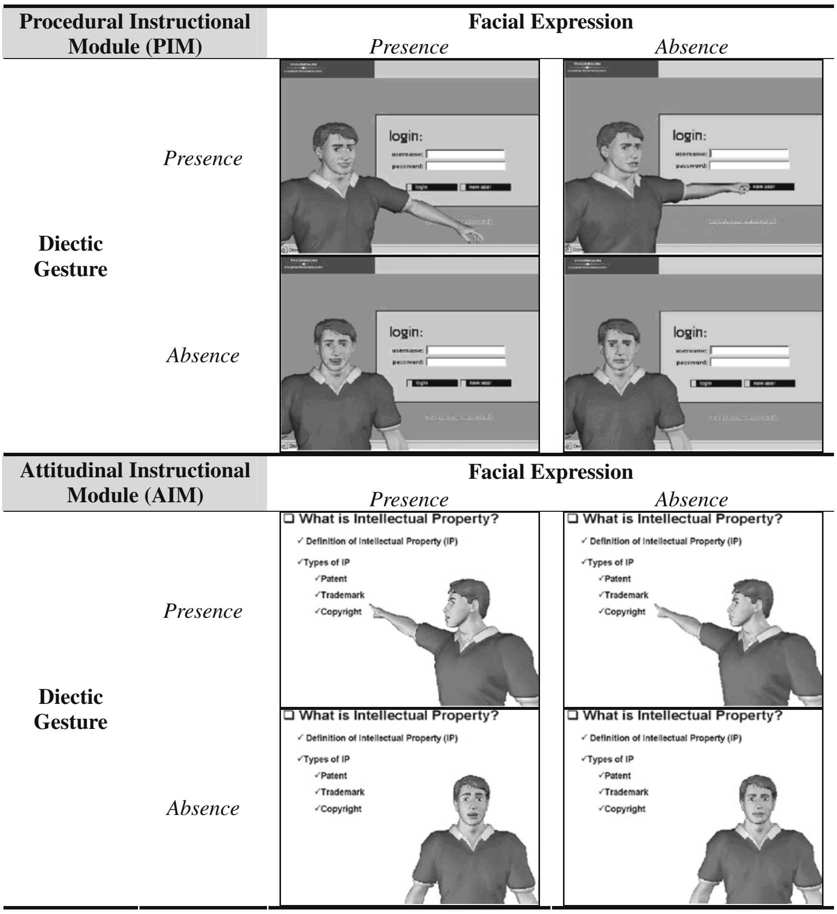

Fig. 1. Sample screen shots for each of the conditions.

property. The content was designed to be relevant to students so that they would not only receive the information but also respond and relate to it, a requirement for attitudinal instruction (Gagné, 1985). Within the module, the pedagogical agent provided information about intellectual property issues and presented the scenarios, encouraging reflection throughout.

2.4. Pedagogical agent

The three-dimensional animated pedagogical agents were developed in Poser©, and audio files were synchronized using Mimic2Pro©. The instructional modules incorporated the agent within a fully integrated web-based environment using Flash MX Professional©.

The agent was purposively chosen to be male for all conditions so as to control for agent gender effects.

2.4.1. Deictic gestures

Deictic gestures in both modules were designed to support the instructional intent and were situated within the computer-based instructional context. Agents' gestures were carefully developed to meet the three criteria of deictic mechanisms: lack of ambiguity, immersivity, and instructional soundness (Lester et al., 2000). For the procedural module, deictic gestures were primarily used to indicate the physical objects and the geographical location of important words or objects on the interface. For the attitudinal module, deictic gestures were incorporated to direct the participants' attention to important informative words or concepts in the instruction. Approximately, 50 instances of deictic gestures were incorporated in both types of instruction; there was no significant difference in number of gestures or distribution of them between the two modules.

2.4.2. Facial expressions

The software Mimic2Pro© was used to create the facial expressions, synchronizing them to the agent's speech. Each agent (within a given module – PIM or AIM) had an identical script and a computer-generated voice, so as to control for any affective influence from the voice. Five different types of facial expression were used: neutral, serious, happy, surprised, and sad. Each type of facial expression had five different levels, from 1 to 5, according to the degree of the emotion. Agents were designed to display appropriate emotion with respect to the content. For example, when the agent talked about laws or rules, it displayed serious facial expressions whereas when it introduced the module and encouraged students to focus, it displayed happier expressions. Given the dynamic nature of the facial expressions, they could not be quantitatively compared across the modules, but were designed to be as similar in number and distribution as possible.

2.5. Measures

To assess the effects of type of instruction with agent nonverbal communication, three dependent variables were employed: (1) attitude toward the content; (2) perceptions of agent persona; and (3) learning. In addition, participants' perceptions of agents' gesture and facial expression were measured.

To assess learner attitude toward the content, learners were asked to list two adjectives that describe what they think about the software program (in the PIM module) or copyright laws (in the AIM module). These pairs of adjectives were scored as three for positive (e.g., necessary, helpful), two for neutral (e.g., descriptive), and one for negative (e.g., bothersome, irritating). This method for assessing implicit attitudes has been used in prior research (Baylor, 2002; Kitsantas & Baylor, 2001). By using descriptive words, learners could make their positive or negative attitude explicit, which was associated with their feelings and evaluational judgments (Bodens & Horowitz, 2002). Two raters scored each student response independently with the pre-determined scoring system. The results of rating between two raters were identical except for six adjective pairs, which were resolved by discussion.

Perceptions with respect to agent persona were assessed by the validated Agent Persona Instrument (API) (Ryu & Baylor, 2005), which includes four sub-measures assessing the extent to which the agent was perceived as: Facilitating learning (10 items), Credible (5 items), Human-like (5 items), and Engaging (5 items).

Learning was assessed by a 10-item test, consisting of true/false, multiple choice, and open-ended questions based on the content from the instructional module (PIM or AIM). Subject matter experts who managed the course curriculum designed the tests in conjunction with the researchers for both instructional modules. The actual items were verified for content validity based on the result of the task-content analysis. While the content of the questions differed for each module, they were developed to be parallel in format. To eliminate the bias of different test construction, the individual test scores were converted into standardized z-scores.

Three Likert-scale items were used to assess participants' perceptions of both the deictic gestures ($\alpha = .95$) and facial expression ($\alpha = .93$). Student perception of the helpfulness of deictic gestures was assessed with three items: (1) The agent's gestures helped me to learn the material; (2) The agent's gestures helped me to pay more attention to what was being said; and, (3) The agent's gestures helped me to focus on learning. Student perception of the agent's facial expressions was measured with three similar items.

2.6. Procedures

The experiment was conducted during regular sections of an introductory computer literacy course and was conducted in two separate phases. In the first phase, the PIM was implemented for 120 participants. Each participant was randomly assigned to one of four conditions varied according to the absence or presence of gesture and facial expression. In the second phase, the AIM was implemented for 117 different participants who had not participated in phase one. Each of these participants was also randomly assigned to one of four conditions, varied according to the absence or presence of gesture and facial expression. Overall, participants were randomly assigned to one of the eight experimental conditions. The participants first responded to 10 demographic questions, and then worked through the instructional module independently, wearing headphones. After completing the instructional module, participants completed an online questionnaire. It took participants approximately 20 min to complete the module and another 20 min for the accompanying questionnaire.

2.7. Data analysis

Descriptive data analysis was conducted to summarize the data. Correlations were analyzed to explain the relationships among variables, including attitude toward the content, perceptions of agent persona, learning, perceptions of agent deictic gestures, and perceptions of agent facial expression.

A three-way MANOVA was conducted to test the overall effect and follow-up ANOVAs were used to detect the effect of independent variables on dependent variables including attitude toward the content, perceptions of agent persona, and learning.

3. Results

There were no missing values in the data. Based on the descriptive analysis, the means and standard deviations for the five variables are summarized in Table 1.

Regarding attitude toward the content, participants in the PIM condition who had an agent with deictic gesture but without facial expression had the highest mean score; however, participants in the AIM condition who had an agent without both gesture and facial expression had the lowest mean score.

With regard to perceptions of agent persona, participants in the AIM condition who had an agent with facial expression and without gesture had the highest mean score, whereas those in the AIM condition with an agent without both facial expression and gesture had the lowest mean score. Those in the AIM condition who had an agent with facial expression and without gesture also learned the most, while those in the AIM condition who had an agent with deictic gesture and without facial expression learned the least.

Table 1
Descriptive statistics.

Variables		Procedural instructional module (PIM)				Attitudinal Instructional Module (AIM)			
		Facial expression (absent)		Facial expression (present)		Facial expression (absent)		Facial expression (present)	
		Deictic gesture (absent) $n = 30$	Deictic gesture (present) $n = 30$	Deictic gesture (absent) $n = 30$	Deictic gesture (present) $n = 30$	Deictic gesture (absent) $n = 20$	Deictic gesture (present) $n = 39$	Deictic gesture (absent) $n = 19$	Deictic gesture (present) $n = 38$
Attitude toward content[a]	M	4.53	4.77	3.80	4.43	3.75	4.41	4.32	4.55
	SD	1.59	1.79	1.97	2.19	1.52	1.53	1.25	1.46
Perception (Agent persona)[b]	M	19.30	21.33	21.50	22.10	17.40	19.38	24.11	20.58
	SD	4.13	6.79	6.31	4.67	7.69	6.21	5.61	7.00
Learning[c]	M	−.22	.10	.14	−.02	−.20	−.31	1.23	−.19
	SD	1.25	1.12	.68	.86	.79	.85	.78	.89
Perception (Agent gesture)[d]	M	13.33	22.73	16.33	21.10	13.15	16.85	20.16	18.00
	SD	6.29	7.38	8.39	7.18	8.03	7.69	7.79	7.45
Perception (Agent facial expression)[e]	M	12.97	15.20	15.27	16.03	15.20	16.46	19.95	17.16
	SD	5.70	9.15	8.02	6.64	9.13	7.00	7.57	7.16

[a] Possible range for attitude toward content (0–6).
[b] Possible range for perception-agent persona (6–34).
[c] The test scores for learning were converted into standardized z-scores.
[d] Possible range for perception-agent gesture (5–35).
[e] Possible range for perception-agent facial expression (5–35).

In addition, those in the PIM condition who had an agent with deictic gesture and without facial expression reported the most positive perceptions of agent gesture, and those in the AIM condition who had an agent with facial expression and without deictic gesture reported the most positive perceptions of agent facial expression.

3.1. Relationships among variables

Table 2 is the summary of the correlations among the five variables in this study. The results indicated that there were significantly high correlations among the participant's perceptions regarding agent persona, gesture, and facial expression. In particular, there was high correlations between perceptions of agent persona and perceptions of gesture ($\gamma = 0.67$), between perception of agent persona and perception of facial expression ($\gamma = 0.70$), and between gesture and facial expression ($\gamma = 0.67$). This implies that learner perceptions of the agent's persona and its nonverbal animations were strongly associated.

Additionally, participants' attitude toward the content significantly correlated with their perceptions of agent persona ($\gamma = 0.16$) and gestures ($\gamma = 0.14$); perceptions of agent persona was significantly correlated with learning ($\gamma = 0.17$).

3.2. Effects of type of instruction, deictic gesture and facial expression

The screening of the data was performed to detect any possible outliers in this study through Mahalanobis D^2 and results indicated that there were no possible outliers. A visual inspection indicated that there was no severe violation of normality assumption. The Levene's test of the assumption of homogeneity of variance was evaluated for each of the dependent variables and results indicated there were no violations of assumptions for MANOVA.

The overall results of the MANOVA indicated that the main effects of facial expression and deictic gesture were each significant at alpha level 0.05, whereas the type of instruction did not have a significant effect on the dependent variables. More importantly, the interactions between the type of instruction and gesture conditions, between the type of instruction and facial expression conditions, and between facial expression conditions and gesture conditions were all statistically significant ($p < 0.05$). Table 3 presents the multivariate analysis of variance summary.

3.2.1. Attitude toward content

The interaction effect between the type of instruction and facial expression significantly influenced participants' attitude toward the content at alpha level 0.1, $F(1,228) = 3.78$, $\eta_p^2 = 0.016$. In the AIM, participants reported a significantly more positive attitude toward the instruction when agent facial expressions were present ($M = 4.47$, $SD = 1.39$) than when they were not ($M = 4.19$, $SD = 1.55$). In contrast, with the PIM, participants reported a significantly more positive attitude toward the instruction when agent facial expressions were absent ($M = 4.65$, $SD = 1.69$) than when facial expressions were present ($M = 4.12$, $SD = 2.09$). These results suggested that the *presence* of agent facial expression enhances positive attitude toward attitudinal content, but the *absence* of agent facial expression enhances attitude for procedural content.

Table 2
Correlations among the variables.

Measure	1	2	3	4	5
1. Attitude toward content	–				
2. Perception (Agent persona)	0.16*	–			
3. Learning	0.10	0.17**	–		
4. Perception (Gesture)	0.14*	0.67**	0.07	–	
5. Perception (Facial expression)	0.11	0.70**	0.06	0.67**	–

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

Table 3
Multivariate analysis of variance summary table.

Variable	Multivariate $F(3,226)$	Univariate: Attitude toward content $F(1,228)$	Univariate: Perception of agent persona $F(1,228)$	Univariate: Learning $F(1,228)$
Type of instruction (K)	.77	0.31	0.70	1.13
Facial expression (E)	7.72*	0.15	10.88*	12.97*
Deictic gesture(G)	4.23*	3.73	0.11	7.61*
K × E	3.55*	3.78	2.24	7.00*
K × G	4.21*	0.00	1.61	11.53*
E × G	5.43*	0.00	4.44*	12.87*

Note: Multivariate *F* ratios are Wilks' Lambda.
* $P < 0.05$.

3.2.2. Perception (agent persona)

The agent's presence or absence of facial expression strongly influenced participants' perception of the agent. Participants who interacted with agents that had facial expressions ($M = 21.78$, $SD = 6.11$) rated the agents' overall persona significantly higher than participants who had an agents with no facial expression ($M = 19.52$, $SD = 6.25$), $F(1,228) = 10.88$, $p < 0.05$, $\eta_p^2 = 0.046$.

The interaction effect between facial expression and deictic gesture was significant at the alpha level 0.05, $F(1,228) = 4.44$, $\eta_p^2 = 0.019$. Participants that had an agent with facial expression but without gestures reported the greatest sense of agent persona ($M = 22.51$, $SD = 6.13$), and participants who had an agent without facial expression but with gestures reported greater agent persona ($M = 20.23$, $SD = 6.49$) than those who had an agent without gesture (i.e., no nonverbal communication) ($M = 18.54$, $SD = 5.82$). Fig. 2 presents the interaction effect between facial expression and gestures on agent persona.

To acquire more detailed information about agent persona results, a separate MANOVA was conducted for the four sub-measures of API, (facilitating learning, credibility, human-likeness, and engaging). Interestingly, the results indicated that the effect of facial expression was significant on all four sub-measures of

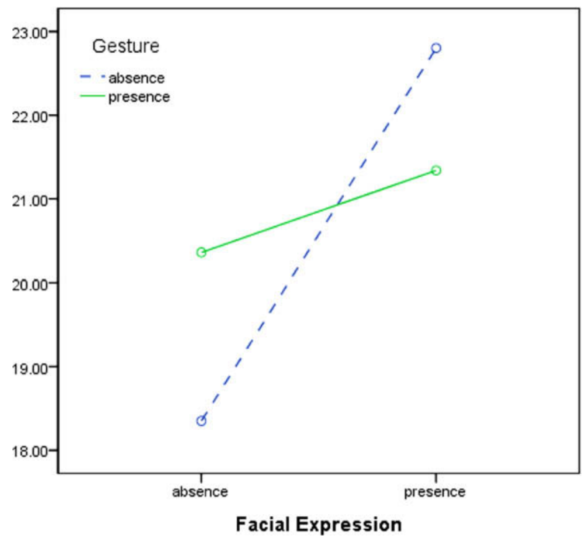

Fig. 2. Interaction effect of facial expression and gesture on agent persona (API scores).

API at the alpha level 0.05, $F = 4.08$, $\eta_p^2 = 0.068$. Specifically, the participants tended to perceive the agent more helpful in facilitating learning when facial expression was present ($M = 21.64$, $SD = 6.51$) than absent ($M = 19.87$, $SD = 6.68$), $p < 0.05$ $F = 6.54$, $\eta_p^2 = 0.028$; they perceived the agent more credible with facial expression ($M = 24.64$, $SD = 6.58$) than without ($M = 23.56$, $SD = 6.48$), $p < 0.05$ $F = 4.25$, $\eta_p^2 = 0.018$; they felt that the agent was more human-like with facial expression ($M = 18.64$, $SD = 7.23$) than without ($M = 16.02$, $SD = 7.14$), $p < 0.05$ $F = 8.94$, $\eta_p^2 = 0.038$; they thought the agent more engaging with facial expression ($M = 22.20$, $SD = 6.48$) than without ($M = 18.54$, $SD = 8.54$), $p < 0.05$ $F = 15.90$, $\eta_p^2 = 0.065$. These results suggest that the presence of facial expression is an important factor in enhancing students' perception of agent persona in learning environments.

3.2.3. Learning

The participants' test scores ranged from 0 to 10 and were converted into standardized *z*-scores so as to compare the scores of the two different tests (from the AIM and PIM). The results of the MANOVA analysis indicated that the main effects of facial expression and gesture on learning were significant ($p < 0.05$).

The interaction of type of instruction and facial expression impacted learning at alpha level 0.05, $F(1,228) = 7.00$, $\eta_p^2 = 0.030$. With the PIM, participants learned more when agent facial expressions were present ($M = 0.06$, $SD = 0.77$) as compared to absent ($M = -0.06$, $SD = 1.19$); with the AIM, the presence of facial expressions ($M = 0.28$, $SD = 1.09$) facilitated learning more than no facial expressions ($M = -.27$, $SD = 0.83$). This result suggests that the effect of facial expression positively influenced learning.

The interaction between type of instruction and gesture significantly influenced learning at alpha level 0.05, $F(1,228) = 11.53$, $\eta_p^2 = 0.048$. Procedural learning was significantly enhanced when agent gesture was *present* ($M = 0.04$, $SD = 0.99$) as compared to absent ($M = -0.04$, $SD = 1.01$), whereas attitudinal learning was facilitated when agent gesture was *absent* ($M = 0.05$, $SD = 1.07$) as compared to present ($M = -0.25$, $SD = 0.87$). This suggests that agent gesture enhanced procedural learning but was detrimental for attitudinal learning.

The interaction between facial expression and gesture also had significant effects on learning, $p < 0.05$ $F = 12.87$, $\eta_p^2 = 0.053$. Most interestingly, when facial expression was absent, the presence of agent gesture enhanced learning ($M = 0.56$ vs $-.11$, $SD = 0.89$ vs .88); in contrast, when facial expression was present, the absence of agent gesture enhanced learning ($M = -0.21$ vs -0.13, $SD = 1.08$ vs .99).

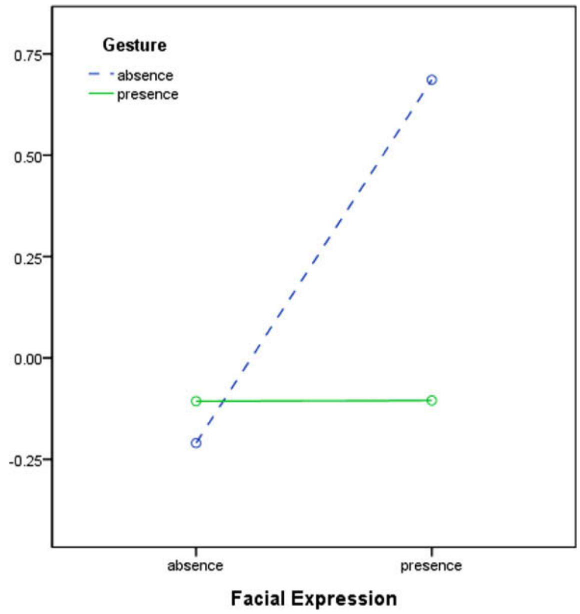

Fig. 3. Interaction effect of facial expression and gesture on learning.

In this study, the interaction of facial expression and gesture was significant on student perceptions of agent persona and learning. As Figs. 2 and 3 show, there was a systematic pattern where facial expression without gesture enhanced agent persona perceptions and learning as compared to agents that had facial expressions together with gesture. Table 4 presents the summary of significant interaction effects in this study, based on the MANOVA analysis results.

4. Discussion

The results of this study verified that pedagogical agents' nonverbal communication plays an important role in enhancing learning-related outcomes. The most interesting finding was that the

Table 4
Summary of significant interaction effects.

Measures	Significant interaction effect		
Attitude toward content	Interaction effect between type of instruction and facial expression, $F(1,228) = 3.78$, $p < 0.10$		
		Facial expression	*No facial expression*
	Procedural module	$M = 4.12$, $SD = 2.09$	$M = 4.65$, $SD = 1.69$
	Attitudinal module	$M = 4.47$, $SD = 1.39$	$M = 4.19$, $SD = 1.55$
Agent persona	Interaction effect between facial expression and gesture, $F(1,228) = 4.44$, $p < 0.05$		
		Facial expression	*No facial expression*
	Gesture	$M = 21.25$, $SD = 6.09$	$M = 20.23$, $SD = 6.49$
	No gesture	$M = 22.51$, $SD = 6.13$	$M = 18.54$, $SD = 5.82$
Learning	Interaction effect between type of instruction and facial expression, $F(1,228) = 7.00$, $p < 0.05$		
		Facial expression	*No facial expression*
	Procedural module	$M = 0.06$, $SD = 0.77$	$M = -0.06$, $SD = 1.19$
	Attitudinal module	$M = 0.28$, $SD = 1.09$	$M = -0.27$, $SD = 0.83$
	Interaction effect between type of instruction and gesture, $F(1,228) = 11.53$, $p < 0.05$		
		Gesture	*No gesture*
	Procedural module	$M = 0.04$, $SD = 0.99$	$M = -0.04$, $SD = 1.01$
	Attitudinal module	$M = -0.25$, $SD = 0.87$	$M = 0.50$, $SD = 1.07$
	Interaction effect between facial expression and gesture, $F(1,228) = 12.87$, $p < 0.05$		
		Facial expression	*No facial expression*
	Gesture	$M = -0.11$, $SD = 0.88$	$M = -0.13$, $SD = 0.99$
	No gesture	$M = 0.56$, $SD = 0.89$	$M = -0.21$, $SD = 1.08$

presence of facial expressions facilitated learning when it was not associated with gesture, and gesture deteriorated the effectiveness of attitudinal instruction while enhancing the effectiveness of the procedural instruction. Additionally, for attitudinal instruction, the presence of facial expression also positively affected learners' perception of agent persona and attitude toward the content. This suggests that having 'one nonverbal communication' for a pedagogical agent may be preferable, designed according to the type of learning (e.g., procedural or attitudinal).

The interaction effect between type of instruction and facial expression revealed that students' attitude toward the attitudinal content was enhanced when agents had facial expressions. In contrast, students' attitude toward the procedural content was enhanced when agents had no facial expressions. The purpose of agent facial expression for the procedural module was to encourage participants to use the software, which in itself is an inherently non-affective task; thus, the expressions may have been perceived as extraneous. As Fogg (2002) pointed out, social cues need to be handled carefully because they can evoke negative responses when inappropriately designed. In contrast, the agent facial expressions within the attitudinal module were a meaningful match, as they situated the nonverbal communication with the instruction.

Along this line, the presence of facial expression positively affected both student perception of agent persona and learning. With regard to perceptions of agent persona, facial expression positively influenced all four sub-components of agent persona, including facilitating learning, credible, human-like, and engaging. With respect to learning, facial expression positively impacted attitudinal learning, as evidenced by high mean learning scores. As researchers have proposed, affective sentiments govern one's attitude (Bodens & Horowitz, 2002; Breckler & Wiggins, 1989). Because the agent's facial expression connoted emotion, it enhanced the persuasion, in particular, for the attitudinal instruction. According to persuasive technology theory, persuasion can be facilitated though the physical social cues from agents (Fogg, 2002). With facial expressions as social cues, pedagogical agents can amplify motivational and social influence to convince learners to choose to accept desirable attitudes.

A particularly interesting finding was the systematic pattern of interaction effects for the agent nonverbal behaviors. The significant interaction effect between facial expression and deictic gesture influenced student perceptions of agent persona and learning. Specifically, when facial expression was present, it was more influential when gesture was absent; conversely, when facial expression was absent, it was more influential when gesture was present. This explanation fits with cognitive load theory – since both facial expression and deictic gestures were visual animations, they may have hindered students' working memory processing when both nonverbal behaviors co-existed (Clark, Nguyen, & Sweller, 2006; Homer, Plass, & Blake, 2008; Mayer, Moreno, Boire, & Vagge, 1999).

The interaction effects between type of instruction and the nonverbal animations were also interesting, since facial expression was effective for attitudinal instruction and gesture was desirable for procedural instruction. The presence of gesture was likely not perceived as educationally meaningful within the context of the attitudinal instruction. The descriptive statistics also presented this pattern in a meaningful way. From the perspective of cognitive load theory, this result can be explained by the concepts of germane and extraneous cognitive load (Clark et al., 2006; Martin-Michiellot & Mendelsohn, 2000; van Merriënboer & Ayres, 2005). In attitudinal learning, agent facial expressions could be perceived as relevant elements of the given content; however, the agent deictic gestures could be perceived as unnecessary and irrelevant components of the affective message. In the case of the procedural instruction, the agent deictic gesture was necessary since it helped learners focus on the steps as the segments of information associated with learning goals. On the contrary, the agent deictic gestures may distract learners during attitudinal learning as an extraneous element. As the results of these mental processes, the agent facial expressions may help in increasing germane cognitive load for attitudinal learning whereas the agent deictic gestures increased germane load for procedural learning.

In conclusion, the presence of agent deictic gestures without facial expression was effective for the procedural instruction and the presence of agent facial expressions without gestures was more effective for the attitudinal instruction. In terms of designing pedagogical agents, this result implies that instructional designers should match agent nonverbal communication with the intended learning outcomes, and for a specific learning outcome, one nonverbal behavior of the agent would be better than two or more animations. In other words, instructional designers should consider the domain of knowledge that they want to represent and transmit, and then decide which type of animation effect will effectively align with the nature of the message. Given that it is not possible to purposely design a human instructor's body to move in particular ways, this is a distinct advantage of animated pedagogical agents. Their nonverbal behaviors can be manipulated to maximize the quality of instruction.

Future work should consider the effects of these nonverbal communicative behaviors when there is increased human-agent interaction within the system. It is true that people tend to interact in social ways when they perceive social presence; social presence can be enhanced by social cues from physical movement of eye, face, hands, and body (Fogg, 2002). Through nonverbal communication, social interaction between the learner and agent play an important role in how the agent is perceived and its effectiveness in message delivery. While these results are valuable for providing initial guidelines for procedural and attitudinal learning outcomes, there are a variety of other learning-related outcomes requiring research.

Results from this study provide practical knowledge about the design of nonverbal communication for pedagogical agents to achieve positive outcomes, for both procedural and attitudinal learning. Unlike human nonverbal communication, agent animations can be designed and controlled to amplify the effect of the message and intensify its meaning in a more effective and efficient way.

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References

Aimeur, E., & Frasson, C. (1996). Analyzing a new learning strategy according to different knowledge levels. *Computers & Education, 27*(2), 115–127.

Allbeck, J., & Badler, N. (2003). Representing and parameterizing agent behaviors. In H. Prendinger & M. Ishizuka (Eds.). *Life-like characters: Tools, affective functions and applications*. Germany: Springer.

Anderson, J. R., Corbett, A. T., Koedinger, K. R., & Pelletier, K. (1995). Cognitive tutors: Lessons learned. *Journal of the Learning Sciences, 4*(2), 167–207.

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

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*, 117–139.

Baylor, A. L., & Kim, Y. (2003). The role of gender and ethnicity in pedagogical agent perception. In G. Richards (Ed.), *Proceedings of World conference on e-learning in corporate government healthcare & higher education 2003* (pp. 1503–1506). Chesapeake, VA: AACE.

Baylor, A. L. (2002). Expanding preservice teachers' metacognitive awareness of instructional planning through pedagogical agents. *Educational Technology Research & Development, 50*(2), 5–22.

Baylor, A. L. (2005). The impact of pedagogical agent image on affective outcomes. In *Proceedings of workshop "Affective interactions: The computer in the affective loop" at the 10th International conference on Intelligent User Interfaces* (pp. 1–6). ACM Press.

Baylor, A. L., & Kim, Y. (2005). Simulating instructional roles through pedagogical agents. *International Journal of Artificial Intelligence in Education, 15*(1), 95–115.

Baylor, A. L., & Plant, E. A. (2005). Pedagogical agents as social models for engineering: The influence of appearance on female choice. In C.-K. Looi, G. McCalla, B. Bredeweg, & J. Breuker (Eds.). *Artificial intelligence in education: Supporting learning through intelligent and socially informed technology* (Vol. 125, pp. 65–72). IOS Press.

Baylor, A. L., Ryu, J., & Shen, E. (2003). The effects of pedagogical agent voice and animation on learning, motivation and perceived persona. In *Proceedings of World conference on educational multimedia, hypermedia and telecommunications* (pp. 452–458). Norfolk, VA: AACE.

Baylor, A. L., & Ryu, J. (2003). The effects of image and animation in enhancing pedagogical agent persona. *Journal of Educational Computing Research, 28*(4), 373–395.

Baylor, A. L., Shen, E., & Huang, X. (2003). Which pedagogical agent do learners choose? The effects of gender and ethnicity. In G. Richards (Ed.), *Proceedings of World conference on e-learning in corporate government healthcare & higher education 2003* (pp. 1507–1510). Chesapeake, VA: AACE.

Baylor, A. L., Shen, E., & Warren, D. (2004). Supporting learners with math anxiety: The impact of pedagogical agent emotional and motivational support. In *Proceedings of workshop on social and emotional intelligence in learning environments at the International conference on Intelligent Tutoring Systems (ITS)* (pp. 6–12). Maceio, Brazil: Springer.

Baylor, A. L., Warren, D., Park, C. H., Shen, E., & Perez, R. (2005). The impact of frustration-mitigating messages delivered by an interface agent. In C.-K. Looi, G. McCalla, B. Bredeweg, & J. Breuker (Eds.). *Artificial intelligence in education: Supporting learning through intelligent and socially informed technology* (Vol. 125, pp. 73–79). IOS Press.

Bodens, K., & Horowitz, I. (2002). *Social psychology*. Mahwah, NJ: Lawrence Erlbaum.

Breckler, S., & Wiggins, E. (1989). Affect versus evaluation in the structure of attitudes. *Journal of Experimental Social Psychology*, 25.

Cassell, J., Sullivan, J., Prevost, S., & Churchill, E. (Eds.). (2000). *Embodied conversational agents*. Cambridge, Mass: MIT Press.

Clark, R., Nguyen, F., & Sweller, J. (2006). *Efficiency in learning: Evidence-based guidelines to manage cognitive load*. San Francisco, CA: Pfeiffer.

Driscoll, M. P., & Burner, K. J. (2005). The cognitive revolution and instrucitonal design. In J. M. Royer (Ed.), *The impact of the cognitive revolution on educational psychology* (pp. 199–229). Greenwich, CT: Information Age Publishing.

Driscoll, M. (2000). *Psychology of learning for instruction*. MA: Allyn & Bacon.

Fogg, B. (2002). *Persuasive technology: Using computers to change what we think and do*. San Francisco, CA: Morgan Kaufman.

Gagné, R. (1985). *The conditions of learning*. New York: Holt, Rinehart & Winston.

Gertner, A. S., & VanLehn, K. (2000). *Andes: A coached problem solving environment for physics.* Paper presented at the ITS 2000, Montreal, Canada.

Graesser, A., Moreno, K. N., & Marineau, J. C. (2003). *AutoTutor improves deep learning of computer literacy: Is it the dialogue or the talking head?* Paper presented at the the international conference of artificial intelligence in education, Sydney, Australia.

Graesser, A., VanLehn, K., Rose, C., Jordan, P., & Harter, D. (2001). Intelligent tutoring systems with conversational dialogue. *AI Magazine, 22*, 39–51.

Gunawardena, C. (1995). Social presence theory and implications for interaction and collaborative learning in computer conferences. *International Journal of Educational Telecommunications, 1*(2), 147–166.

Heeter, C. (1995). Communication research on consumer VR. In F. Biocca & M. Levy (Eds.), *Communication in the age of virtual reality*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Homer, B., Plass, J., & Blake, L. (2008). The effects of video on cognitive load and social presence in multimedia-learning. *Computers in Human Behavior*, 24.

Johnson, W. L., Rickel, J. W., & Lester, J. C. (2000). Animated pedagogical agents: face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education, 11*, 47–78.

Kim, Y., & Baylor, A. L. (2006). A social-cognitive framework for pedagogical agents as learning companions. *Educational Technology Research & Development, 54*(6), 569–590.

Kim, Y., & Baylor, A. L. (2007). Pedagogical agents as social models to influence learner attitudes. *Educational Technology, 47*(1), 23–28.

Kim, Y., Baylor, A. L., & Reed, G. (2003). The impact of image and voice with pedagogical agents. In G. Richards (Ed.), *Proceedings of World conference on e-learning in corporate, government, healthcare, & higher education 2003* (pp. 2237–2240). AACE: Chesapeake, VA.

Kitsantas, A., & Baylor, A. L. (2001). The impact of the IPSRT (instructional planning self-reflective tool) on preservice teachers' performance, disposition, and self-efficacy beliefs regarding systematic instructional planning. *Educational Technology Research & Development, 49*(4), 101–110.

Lee, K. M., & Nass, C. (2003). Designing social presence of social actors in human computer interaction. In *Proceedings of the SIGCHI conference on human factors in computing systems*.

Lester, J., Towns, S., Callaway, C., Voerman, J., & Fitzgerald, P. (2000). Deictic and emotive communication in animated pedagogical agents. In J. Cassell, J. Sullivan, S. Prevost & E. Churchill (Eds.), *Embodied conversational agents*. Cambridge, MA: The MIT Press.

Martin-Michiellot, S., & Mendelsohn, P. (2000). Cognitive load while learning with a graphical computer interface. *Journal of Computer Assisted Learning, 16*.

Mayer, R., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal of Educational Psychology, 91*(4), 638–643.

McIssac, M., & Gunawardena, C. (1996). Distance education. In D. Jonassen (Ed.), *Handbook for research on educational communication and technology*. New York, NY: Scholastic Press.

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.

Mousavi, S., Low, R., & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology, 87*(2), 319–334.

Mykota, D., & Duncan, R. (2007). Learner characteristics as predictors of online social presence. *Canadian Journal of Education, 30*(1), 157–170.

Nam, C., Shu, J., & Chung, D. (2008). The roles of sensory modalities in collaborative virtual environment (CVEs). *Computers in Human Behavior, 24*(4), 1404–1417.

Newberry, B. (2001). Raising student social presence in online classes. ERIC Document Reproduction Service No. ED 466 611.

Reeves, B., & Nass, C. (1996). *The media equation*. Stanford, CA: CSLI Publications.

Romiszowski, A., & Mason, R. (2004). Computer-mediated communication. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology*. Mahwah, NJ: Lawrence Erlbaum Associates.

Rosenberg-Kima, R., Baylor, A. L., Plant, E. A., & Doerr, C. (2008). Interface agents as social models for female students: the effects of agent visual presence and appearance on women's attitudes and beliefs. *Computers in Human Behavior, 24*(6), 2741–2756.

Ryu, J., & Baylor, A. L. (2005). The psychometric structure of pedagogical agent persona. *Technology Instruction Cognition & Learning (TICL), 2*(4), 291–315.

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication, 42*, 73–93.

van Merriënboer, J., & Ayres, P. (2005). Reseach on cognitive load theory and its design implications for e-learning. *Educational Technology Research & Development, 53*(3), 5–13.