



Pedagogical-Agent Learning Companions in a Virtual Reality Educational Experience

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Abstract. This research studies pedagogical agents as a learning companion (PALs) and aims to find which approach is more effective for learners in terms of learning, engagement and rapport: a PAL that is the same gender as the student, a PAL that is female, or a PAL that is male. We compared results in terms of learning and rapport with respect to the gender of a PAL. To this end, we implemented a multimodal interactive virtual-reality application to teach students about the 1770 Boston Massacre. Our results suggest that (1) both male and female participants will learn well with a female PAL, and (2) differences in rapport do not seem to affect learning.

Keywords: Embodied conversational agents · Human-agent dialog · Dialog system

1 Introduction

Virtual worlds are great tools for research, training, entertainment, and education. Even though virtual worlds have served well as an innovative supplementary tool for presenting educational content, students' learning is influenced by social aspects that virtual environments alone cannot accommodate. To address this problem, virtual agents can take advantage of social affordances to accomplish a learning task [9]. As a result, educational virtual environments that incorporate a virtual agent are more engaging and motivating to learners than the virtual environment alone [8].

Embodied conversational agents (ECAs) [4] are virtual characters that are placed in a virtual environment and may have different functions and different levels of interaction with a user (if any). ECAs serve in a variety of fields, such as entertainment, training, customer service, and education. In education, specifically, ECAs provide supplementary motivation and pedagogy as tutors, learning companions, mentors, tutees, and other pedagogical roles. ECAs whose

role is educational are termed Embodied Pedagogical Agents (EPAs) [6]. EPAs can model different instructional roles, such as instructors, mentors, and learning companions. Their goal is, of course, to increase the student’s proficiency in the material being taught by the EPA. Some EPAs have a secondary goal to engage students and in this way to increase their motivation to learn. Strategies to help EPAs achieve engagement have included changing their appearance, their teaching style, and the roles they play within the learning environment [2, 5, 6]. For example, children aged 7 to 11 chose an EPA learning companion over an EPA instructor to teach them multiplication, where children indicated that they could relate more to the learning companion and trusted the EPA [5].

In educational experiences conducted in virtual reality (VR), the user is typically guided by a pedagogical agent as a learning companion (PAL) [9]. While the prevailing consensus is that children tend to prefer agents that look like themselves (e.g., [2, 10]), the effect of the PAL’s gender on learning, rapport, and engagement is an open question. Johnson, DiDonato, and Reisslein [7] reported that children (K-12) preferred an embodied pedagogical agent that represents a young woman close to their age as a virtual learning companion. Conversely, Baylor and Kim [1] found that students showed higher interest when working with a male PAL. Other studies have looked at not only the PAL’s gender but the also preference of the student based on the gender. Haake and Gulz [6], for example, found that female students tended to prefer a task- and relation-oriented communication style for their learning partner. The split in the research results makes it difficult for developers of virtual-reality educational experiences to choose the most effective PAL. Accordingly, our research aims to find which approach is more effective for learners in terms of learning, engagement, and rapport: a PAL that is the same gender as the student, a PAL that is female, or a PAL that is male.

2 The Boston History Experience

We addressed the question of students’ PAL gender preference and effectiveness by comparing learning and rapport outcomes as a function of the gender of a PAL and the gender of the student. To this end, we implemented a multimodal interactive virtual-reality application to teach students about the Boston Massacre in 1770 [12]. In the application, students explore the city of Boston with an assigned PAL that plays the role of a house worker, while the user plays the role of John Adams’s apprentice. In the interaction, the user walks alongside the PAL while having conversations with seven ECAs, representing characters such as Abigail Adams, a tea-shop owner, and a redcoat (see Fig. 1). The interaction between the student and the virtual agents concludes with a conversation with Abigail Adams in which the students explain what they learned and narration by John Adams about events that followed. A final non-interactive cinematic sequence presents additional facts about the events that unfolded after the Boston Massacre.



Fig. 1. Lydia, a pedagogical agent as a learning companion, and a redcoat, in the Boston Massacre history experience (Color figure online)

The application is fully functional, and the experience lasts about 20 min. The application was implemented in the Unity game engine, using the UTEP AGENT system [11] and the Microsoft speech recognizer, and was delivered via the HTC Vive VR headset. To assure accuracy, the script was developed in collaboration with a professor of history. Table 1 presents samples of the application’s dialog with some of the virtual agents, with the PAL prompting the student.

For the setting, we created a virtual representation of the central section of Boston in 1770, with dozens of extra agents on the streets (see Fig. 2). The agents representing the characters, including John and Abigail Adams (see Fig. 3), Joshua, a tea-shop owner (see Fig. 4(a)), and Phoebe, a slave (see Fig. 4(b)), speak with recorded voices. Background music was composed and recorded especially for the application by a professional composer.

3 Methodology

Our study had two independent variables, the PAL’s gender and the student’s gender. For the first variable, the VR experience had two versions. In one version, the PAL is a female character named Lydia. In the second version, the PAL is a male character named Henry (see Fig. 5). The information material presented to the participants in both versions was the same; the only aspect that differed was the gender of the PAL. Half of the participants interacted with the female agent Lydia, and the other half interacted with the male agent Henry. We hypothesized that:

- Subjects interacting with the female PAL will perform better in recalling facts
- Subjects interacting with the female PAL will report higher rapport
- Subjects interacting with the PAL of the subject’s gender will perform better in recalling facts



Fig. 2. Virtual Boston, with dozens of (non-speaking) agents on the streets, was modeled after the streets of Boston in 1770 close to the customs house.



Fig. 3. Embodied conversational agents in the roles of John Adams and Abigail Adams.

Table 1. Samples of agents' utterances, with prompts from the PAL.

	Agent utterance	PAL prompt
Joshua, tea-shop owner	You mean that ruckus? I didn't see it. I was here tending to my shop. Those redcoats will get what is coming to them, and that Townshend Revenue Act? Pff?!	Revenue Act? Ask him about that.
Phoebe, slave	Please, I'm not supposed to be here. Just leave me alone. (pause) A group of soldiers fired on a crowd. Everyone is busy choosing sides. Not that it matters anyway.	Why not? What side are you on? Why don't you care? Why wouldn't it matter
Phoebe, slave	I am still a slave. I will always have a master above me, and I will always do the same job. My voice doesn't matter.	She said she wasn't supposed to be here. Ask her what she's doing here.
Paul, Patriot	They're suffocating us! These new laws are far too harsh!	Laws? Ask him what laws he is talking about.
Hugh, Soldier	We fought the 7 years war on your behalf to keep you safe. We are just trying to recover some of what we have lost. And we are innocent for what happened last night. Did you not see the mob surround us?	N/A

**Fig. 4.** Embodied conversational agents in the role of (a) Joshua, the owner of tea shop, and (b) Phoebe, a slave.

- Subjects interacting with the PAL of the subject’s matching gender will report higher rapport
- Subjects who report higher rapport with the PAL will perform better in recalling facts

The study used a between-subjects design with 90 participants (69 male and 21 female), all undergraduate students at a public university, who were randomly assigned to one of the four conditions.



Fig. 5. PAL companions Lydia (*left*) and Henry (*right*)

The study had two dependent variables, rapport and learning. We measured rapport with a post-interaction Likert-scale survey adapted from [3]. Table 2 presents the ten items in the survey, plus an additional open-ended question for qualitative responses. We measured learning with a post-interaction quiz, developed with the help of our consulting professor of history, presented in the appendix. The quiz had ten questions, six of which were multiple choice, two were true or false, and two were fill-in-the-blank.

4 Results

Our first hypothesis was that subjects interacting with the female PAL would perform better in recalling facts. The mean learning scores for students interacting with the male and female PALs were 53.1 and 56.0, respectively, but this difference was not significant (one-tailed t test, $p > 0.15$). If there is an effect, the effect appears to be small. Figure 6 shows the results for rapport and learning, differentiated by the two independent variables, PAL gender (L[ydia] or H[enry]), and participant gender (F or M). Table 3 reports the values across all conditions.

Table 2. Post-interaction rapport survey questions

1	The agent understood me
2	The agent seemed unengaged
3	The agent was excited
4	The agent’s movements were not natural
5	The agent was not paying attention to me
6	The agent was friendly
7	The agent and I worked towards a common goal
8	The agent and I did not seem to connect
9	I feel the agent trusts me
10	I didn’t understand the agent
11	The conversation would feel more real if the agent...

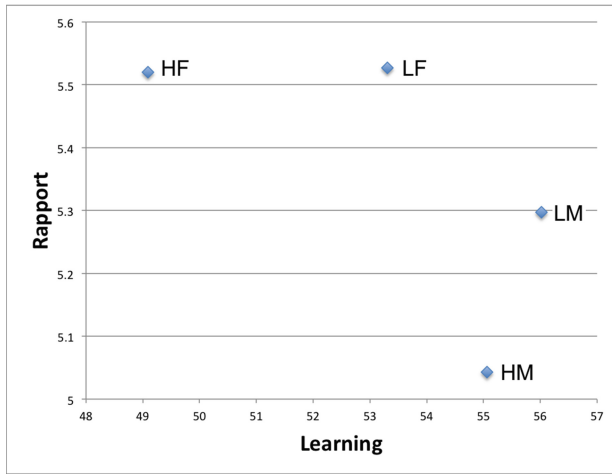


Fig. 6. Distribution of results (rapport and learning), differentiated by gender of PAL (L[ydia] or H[enry]) and gender of participant (F or M).

Our second hypothesis was that subjects interacting with the female PAL would report higher rapport. There is suggestive evidence that this is true, as can be seen in Fig. 4. The mean rapport scores for students interacting with the male and female PALs were 4.48 and 4.65, respectively. A t-test indicates that this is suggestive of a significant difference (one-tailed t-test, $p < 0.08$).

Our third hypothesis was that subjects interacting with the PAL of the subject’s gender would perform better in recalling facts. Again, the evidence mildly suggests that this is true. The mean learning scores for same-gender and opposite-gender student-agents pairs were 56.8 and 52.2, respectively. A t-test indicates that this is possibly suggestive of a significant difference (one-tailed t-test, $p < 0.10$).

Table 3. Summary statistics for information recall and rapport, as a function of the gender of agent and participant.

Agent	Participant	Mean learning	Mean rapport
Henry	Male	55.07	5.04
Henry	Female	49.09	5.52
Lydia	Male	56.02	5.30
Lydia	Female	53.31	5.53

Our fourth hypothesis was that subjects interacting with the PAL of the subject’s gender will report higher rapport. Our data suggest that is not true. The mean rapport scores for same-gender and opposite-gender student-agents pairs were 4.53 and 4.58, respectively. A t-test indicates that this difference is not significant (two-tailed t-test, $p > 0.67$). Indeed, the mean scores were slightly opposite of the expected effect.

Our fifth hypothesis was that subjects who report higher rapport with the PAL will perform better in recalling facts. As suggested by the scatter plot shown in Fig. 7, there appears to be no correlation between learning and rapport. The correlation is less than 0.0003, and R^2 is 6.56E-08.

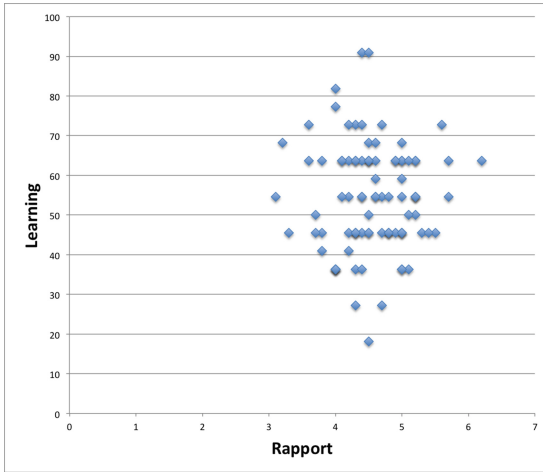


Fig. 7. Scatter plot of results (rapport and learning)

Table 4 shows the performance of all participants for each question. Multiple-choice question seven asked student which of four multiple choice responses was false. Correctly, none of the all 90 participants selected as false the response “Slavery existed in Boston at the time of the Massacre.” We speculate that the reason for this being an obvious wrong choice was because the students had interacted with a slave as part of the experience.

Table 4. Percentage of people who scored the correct response for each question in the questionnaire for fact recall. Details of the questions are provided in the appendix.

	Category	Questionnaire	Correct overall	Correct Lydia	Correct Henry
1	Multiple choice (4)	What happened at the Boston Massacre?	93.3%	95.6%	91.1%
2	Multiple choice (4)	What word does not describe the Boston Massacre?	92.2%	93.3%	91.1%
3	Short answer	The Boston Massacre occurred in front of the ...	21.1%	20.0%	22.2%
4	True/False	The British imposed the Stamp Act upon the colonies several years before the Boston Massacre.	58.9%	60.0%	57.8%
5	Multiple choice (4)	Which of the following best describes the Revenue Act?	65.6%	68.9	62.2%
6	Multiple choice (4)	The Declaratory Act allowed the British the complete authority to...	74.4%	73.3%	75.6%
7	Multiple choice (4)	Which of the following is FALSE?	51.1%	55.6%	46.7%
8	True/False	John Adams defended Crispus Attucks and his fellow colonists.	54.4%	55.6%	53.3%
9	Short answer	Which TWO people were found guilty for the Boston Massacre?	12.78%	11.1%	14.4%
10	Multiple choice (4)	Which of the following is TRUE?	75.6%	75.6%	75.6%

Limitations. This study's results are subject to two possible limitations. First, the study had a gender imbalance of participants, with more males than females. By the conclusion of the experiment, 35 males and 10 females interacted with PAL companion Henry while 34 males and 11 females interacted with PAL companion Lydia. This distribution reflected the underlying student population of the college in which the participants were enrolled but made less reliable the findings with respect to female participants. Second, the Boston Massacre History Project application was designed for eighth-grade students, but despite agreement from a middle-school principal we were unable to obtain permission from the school district to conduct the study with eighth-graders. Consequently, the study's participants were undergraduate students, whose learning styles and rapport preferences may differ from those of eighth-graders.

5 Conclusion

Our data suggest that female participants with the female PAL learned more than female participants with the male PAL, even though female subjects, on average, reported the same level of rapport regardless of the gender of the PAL. Our data also suggest that male participants learned marginally more with the female PAL than with the male PAL, although the male participants, on average, reported slightly higher rapport with the male PAL. These results suggest that (1) both male and female participants will learn well with a female PAL, and (2) differences in rapport do not seem to affect learning.

Appendix: Questionnaire for Boston History Fact Recall

The following is the questionnaire used after the BHE to measure the participant's fact recall

1. What Happened at the Boston Massacre?
 - (a) A rowdy colonial crowd killed several British soldiers
 - (b) British soldiers killed several rowdy colonists
 - (c) The New York Yankees swept the Boston Red Sox in the playoffs
 - (d) Wampanoag Indians attacked Boston and killed several colonists
2. What word does not describe the Boston Massacre?
 - (a) Violent
 - (b) Tense
 - (c) Scary
 - (d) Amusing
3. The Boston Massacre occurred in front of the _____
4. The British imposed the Stamp Act upon the colonies several years before the Boston Massacre
 - (a) True
 - (b) False
5. Which of the following best describes the Revenue Act?
 - (a) a tax on documents and other printed materials
 - (b) an act requiring colonists to provide housing for British soldiers
 - (c) a tax on goods, such as tea
 - (d) an act forbidding colonists from protesting British laws
6. The Declaratory Act allowed the British the complete authority to....
 - (a) impose laws on the colonies
 - (b) regulate trade in the colonies
 - (c) tax printed materials in the colonies
 - (d) send British troops throughout the colonies
7. Which of the following is FALSE?
 - (a) The Boston Massacre was a peaceful protest turned violent
 - (b) The Boston Massacre occurred in 1770
 - (c) Slavery existed in Boston at the time of the Massacre
 - (d) John Adams was married to Lydia Adams

8. John Adams defended Crispus Attucks and his fellow colonists
 - (a) True
 - (b) False
 9. Which TWO people were found guilty for the Boston Massacre?
-
10. Which of the following is TRUE?
 - (a) British soldiers did not compete with colonists for jobs
 - (b) British soldiers built their own homes in Boston
 - (c) Colonists resented the presence of British soldiers in Boston
 - (d) Colonists were required to serve British soldiers tea

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