The Role of Embodied Conversational Agents in Collaborative face to face Computer Supported Learning Games

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ABSTRACT

Studies show that face to face collaborative videogames have a great potential to improve the quality of education in the classroom of the future. Educational games can help pupils increase cognitive skills, increase motivation and reduce the time taken to reach learning objectives. Games used in a group environment can enrich the learning experience further still by helping develop group social skills and exploiting social dynamics toward achieving a common learning objective. Despite these advantages the uptake of collaborative games as learning tools in the classroom is still relatively low. While collaborative working has proven advantages they also suffer from an incompatibility with the ingrained individualism of traditional education. Moreover, collaborative working can disadvantage introverted students, suffer from conflicts within a group or allow less motivated students to avoid making a contribution. The work described in this paper investigates the viability of these disadvantages being managed through the intervention and mediation of an intelligent embodied conversational agent with awareness of group activity acting as a virtual tutor. Here we examine how students perform and collaborate using a variety of games to; learn words in a foreign language, solve mathematical equations, and add missing words to a paragraph of text. These respectively aim to develop the students' memorization, basic reasoning, and creative vocabulary. Our embodied virtual agent is emulated using a wizard-of-oz set up with a human controlling the embodied agent Samuela using a basic scripted interaction strategy. To qualify our results, they are contrasted with those obtained with an unsupervised group and a group supervised by a human tutor.

Keywords: Human Computer Interaction, Educational Videogames, Collaborative Learning, Embodied Conversational Agents

1. INTRODUCTION

Embodied Conversational Agents (ECAs) [1] are intelligent agents - software endowed with particular capabilities, such as the ability to learn, adapt and evolve in an environment. In addition, as highlighted by Cassel, they are particularly conversational [2] form a new metaphor for human-computer interaction, which aims at providing people with the illusion that they are interacting with a human partner rather than just a "simple machine" [3]. This paper considers the extent to which an ECA can help students achieve specific learning objectives and to what extent an ECA can support collaboration among a group of students. We also look at how students regard an ECA and what role they can fulfill in a collaborative educational gaming environment.

2. METHODOLOGY

In order to investigate the role of ECAs in collaborative learning games we undertook an experiment that allowed us to observe children using a variety of collaborative games with and without the assistance of an ECA. Before and after the experiments the children were given written tests to assess specific learning objectives and during the tests we recorded audio and video. We also asked the students to complete questionnaires to determine how they felt about the level and quality of collaboration.

Our experiments involved six groups of three children aged eight to ten years. Each group spent two hours playing educational videogames. Half of the groups were joined by Samuela, the ECA virtual teaching assistant, and half were unsupervised. Four groups were all female (two with and two without Samuela) and two groups all male (one with and one without). Each child was tested immediately before, immediately after and four days after their session with Samuela. The exams used for this testing included three five minute sessions testing mathematics, languages and reading. Three versions of each exam were created so that no two students in the same group would do the same exam at the same time and no one student would do the same exam twice. This helped ensure that any differences in difficulty between the questions would average out over the course of the experiment.

The set-up of the experiment is shown in figure 1. Games were played on a forty-two inch screen angled at forty-five degrees and raised between waist and head height. The children were observed through two-way glass with audio and video recorded throughout. When our ECA, Samuela, was involved in experiments, she was controlled using a wizard-of -oz set-up visible to the students on a separate 26 inch monitor. The students were not made aware that Samuela was operated by a human controller.

Figure 1. The set-up of our experiment. On the left we see the games room where our groups of three students play educational video games using a forty-two inch multi-touch monitor with, or without, the assistance of Samuela, the ECA virtual teaching assistant. On the right is the control room where the controller can observe students in the games room through two-way glass and type words into a laptop to control how Samuela speaks-to and interacts with the children.

2.1 Educational Videogame Design

Three educational games were developed for our experiment. In order for the games to be both accessible and challenging for children with different levels of learning, we tried to incorporate a gradually increasing level of difficulty. Other key aspects of game design were cultural relevance and age appropriateness. Here we tried to ensure that the games were non-violent and did not enforce gender stereotypes while encouraging the children to identify with elements of their native Mixtec and Mexican culture. An example of this was the use of native Mixtec codices used as sprites to represent game characters (see figure 2).

Figure2. Mixtec codices used as characters in the mathematics and languages videogames: Jaguar, eagle, muerte and mixteco.

2.1.1 Mathematics game

The mathematics game (figure 3 LHS) is a simple 'castle defense' type game where the students have to solve mathematical equations to fire eagles and prevent the muertes from reaching the perimeter wall of their town and draining their energy. The character of the user, the jaguar, sits at the left hand side of the screen. Below this character is a keypad and to the right a list of sums. To the right of the sums is a vertical wall and beyond the wall are the muertes. Each muerte advances slowly from right to left toward a sum and if a muerte reaches the wall it stops and begins to drain the health of the user. When the health of the user reaches zero the game is over. In order to stop muertes reaching the wall the user can answer sums to fire eagles. The user can press on different sums to answer them using the keypad. If a sum is answered incorrectly health is drained and if a sum is answered correctly an eagle is fired from the wall toward the right hand side of the screen. When a muerte is hit by an eagle it is pushed back away from the wall. Pushing back muertes also adds to the users score and causes the level-up bar to rise. When the level up bar is full, every sum fires an eagle to push all the muertes back and the user progresses to the next level. As the level increases, the muertes begin to speed up and it becomes gradually more difficult to do all the sums on time and keep the muertes away from the wall.

2.1.2 Languages game

The second game encourages students to learn the names of animals in English (figure 3 top right). This game is a similar 'castle defense' type game to that used to learn mathematics described above. However, instead of doing sums to fire eagles the students have to match words in English to their Spanish translations. When words are matched correctly eagles are fired from both words and health is drained when words are matched incorrectly. The game begins with a small number of words for more common animals such as cats and dogs. As the game advances the difficulty level increases with a wider variety of gradually more obscure animal names. If the children are not already familiar with the names of these animals in English, they can normally find the translations out by trial and error and learn from their mistakes.

2.1.3 Reading game

The third game (figure 3 bottom right) aims to help the children with reading by asking them to complete a story by replacing missing verbs. Literature and authors are held in particular esteem in Mexico, and Latin America in general, with popular

authors often becoming diplomats or politicians. This game encourages the children to explore the Mexican side of their identity by using an adaptation of the short story 'Mi vida con la ola' by Mexican Nobel laureate for literature Octavio Paz. During the game, text from the story with missing words moves toward the top of the screen. The user can replace missing words from a list of words at the right hand side of the screen. If a word is replaces successfully the score increases. If however the children attempt to enter the wrong verb into a space, health is drained. Likewise if the space for a missing word reaches the top of the screen without being filled, health is drained and the text stops scrolling until a correct word is entered. While the text is scrolling the health replenishes slowly and as the children progress through the text by replacing words, the missing words become more frequent so as to make the game more difficult.

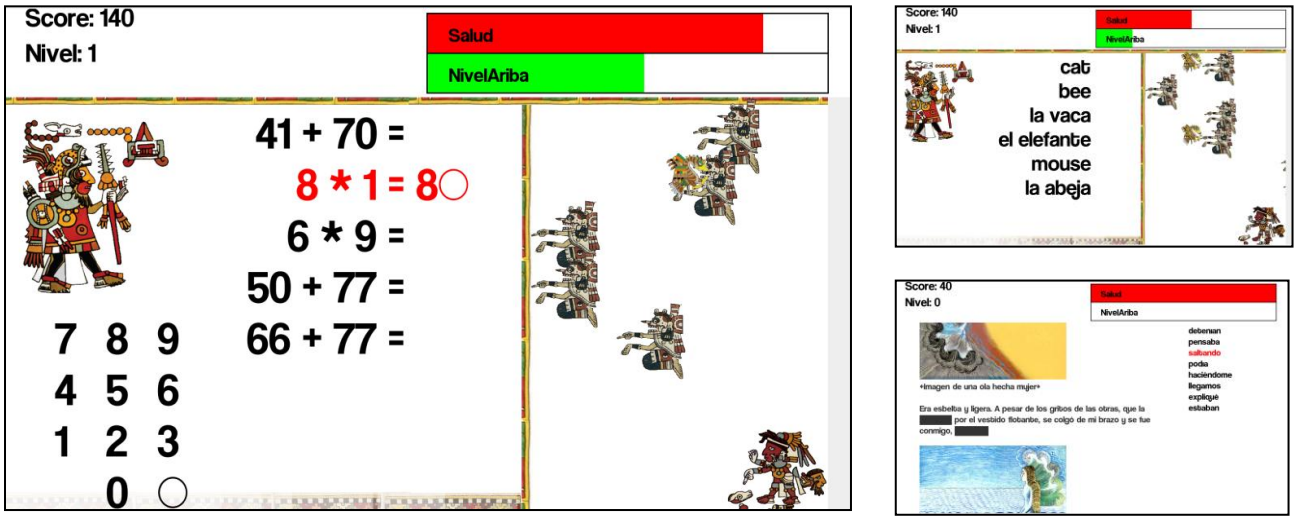

Figure 3. Screenshots of the educational videogames; left mathematics, top right languages and bottom right reading.

2.2 Samuela, the virtual teaching assistant

The overall objective of our study was to investigate the role of an ECA in collaborative learning using educational games. To achieve this, half of our experiments involved an ECA acting as a teaching assistant with the other half unsupervised. Comparing results from the two experiments allowed us to quantify the positive impact of an ECA on collaborative learning.

Figure 4. Samuela, the ECA virtual learning assistant. Left, how Samuela appears on the screen, and right, Samuela interacting with a group of children in the games room.

2.2.1 Implementation

To emulate an ECA in our experiment we used a Wizard of Oz set-up [4, 5]. This involved an avatar controlled by an unseen human operator giving the impression of an autonomous system. This allowed us to emulate an ECA running under ideal conditions without any of the undesirable artifacts, such as slow or inappropriate responses, that might be evident if we decided to use an actual autonomous ECA. This also allowed us to avoid having to rely on non-mature technologies such as imperfect speech and emotional recognition that would be likely to become a cause of unnecessary confusion during the experiments.

The avatar used in our experiment, Samuela, was originally developed by Telefónica R&D using Hapteck Software for the European Union funded project Companions [6, 7]. The original version of Samuela used in the project spoke English and was

northern European in appearance with blonde hair and blue eyes. To make Samuela more familiar and understandable for the students involved in our study based in the Mixteca region of Mexico we changed Samuela's language to Latin-American Spanish and her hair color to dark brown (see figure 4). In order to make Samuela speak we developed a basic interface that allowed the operator to type words and have them sent to Samuela by pressing the return key. This ran on the same laptop computer as Samuela using a different monitor. The monitor to view Samuela was placed in the games room with the children and the laptop computer with the control interface was left in the observation room.

2.2.2 Interaction strategy

The basic interaction strategy adopted for Samuela by our operator was to try to act as a teaching assistant or tutor for children working on a group project. Initially, Samuela would introduce herself and ask the names of the students. Samuela would also introduce the games and help with any difficulties the students had understanding how the games worked. She could suggest basic strategies such as trying to fire eagles at the muertes closest to the wall first. She would also encourage the students when they got a difficult question right or reached a new level in the game. If a student became disengaged from the group Samuela could ask them what was the matter and encourage them to participate. Likewise, if a group member came to dominate the game without letting their fellow students participate, Samuela would suggest that another student take their turn answering the questions. If Samuela was directly approached to give the answer to a question she would provide an answer only the first few times, after this she would take longer to give the answer the question or suggest a strategy the students might use to solve the problem themselves. Samuela could also try different strategies to engage with the students in other ways such as asking them if they enjoyed the game or which games they preferred. This helped the student identify with Samuela as something more like a real person and not just as part of the game. If the students asked Samuela questions about her origin or how she worked, she would answer in the role of a synthetic character endowed with artificial intelligence. This was done without revealing how she was operated manually.

3. RESULTS

Our experiments provided us with three types of results. Firstly, short exams taken by the students immediately before, immediately after and four days after the experiments allowed us to assess how the games contributed towards specific short-term learning objectives with and without Samuela. In addition to these exams, the students were asked to fill in questionnaires to provide us with more subjective information relating to how the students felt about working as a team. Finally, observations made during the tests allowed us to observe the dynamics of the groups and how strategies evolved during the sessions.

3.1 Exam results

Table 1 summarizes the improvement in the children's performance in the exams after the session with the educational games with and without Samuela. Here we can see that the children's performance did not improve much immediately after their session with the games. This was most likely due to the children being tired and over-stimulated after playing the games for two hours. When the students were tested again, four days after the tests, there was a significant improvement in their performance. This improvement was particularly marked for mathematics where the student's performance showed an increase of 21.9%. The improvement for languages was 4.3% and the students regressed slightly in their reading (by 2.1%). In order statistically validate our results and account for inter-sample variance we performed a single-tailed t-test. This gave a p-value of 0.016 for the second test to indicate that it was highly likely the children's improvement was due to their exposure to the games rather than variation of the children's scores overall. The p-value for improvement in the mathematics test was 0.0018 indicating a greater probability that the children's improvement was due to their exposure to the games. The p-value for the language test was marginal at 0.20 (0.089 for the boys) indicating that there is insufficient evidence to conclude that exposure to the games caused an improvement in the children's results (using the standard p-value threshold of 0.05). Results also indicate that there is insufficient evidence to conclude that the *drop* in reading performance is due to exposure to the reading game (with a p-value of 0.38).

		Improvement in performance							
		Immediately after the test				four days after the test			
	With Samuela	Maths	Languages	Reading	All	Maths	Languages	Reading	All
girls	yes	10.8%	5.1%	-2.1%	**4.6%**	23.3%	2.6%	-6.3%	**6.5%**
	no	9.2%	-3.2%	2.1%	**2.7%**	20.8%	2.6%	8.3%	**10.6%**
boys	yes	11.7%	-5.1%	-16.7%	**-3.4%**	20.0%	6.4%	-4.2%	**7.4%**
	no	6.7%	3.8%	-33.3%	**-7.6%**	23.3%	9.0%	-12.5%	**6.6%**
all children	yes	11.1%	1.7%	-6.9%	**2.0%**	22.2%	3.8%	-5.6%	**6.8%**
	no	8.3%	-0.9%	-9.7%	**-0.7%**	21.7%	4.7%	1.4%	**9.3%**
All students with and without Samuela		**9.7%**	**0.4%**	**-8.3%**	**0.6%**	**21.9%**	**4.3%**	**-2.1%**	**8.0%**

Table 1. Improvement in child performance assessed by exams administered after a session with collaborative educational games.

Despite the improvement in the children's performance being more apparent in the final exam four days after the games session, the influence of Samuela appeared to be more apparent in the exam immediately after the test. Here the children seemed to perform about 2.7% better with Samuela. This was not however a statistically significant improvement and the trend actually appeared to be reversed in the exam applied four days after the test.

3.2 Questionnaire results and observations

The questionnaires filled in by students and observations made during the experiments provided us with more subjective information regarding how our ECA teaching assistant was able to affect group performance. In general, the results of the questionnaire indicated that the children who worked with the assistance of Samuela fostered a more positive attitude toward the use of the games to learn. These children also felt more positive about the benefits of collaborating to learn. We also noticed that the children helped by Samuela had less of a tendency to disengage during the test sessions and showed more willingness to involve themselves in a group strategy. For example, while using the reading game the children working with Samuela showed more of a tendency to read out loud and discuss their choices. When playing the math game, the children not operating the interface would suggest answers or assign themselves to work on another more difficult question. At other times a child would be delegated to speak to Samuela while other students were answering questions. The students working without Samuela tended to take turns operating the interface of the game without contributing when it was not their turn to use the interface. Overall, the presence of Samuela appeared to have a positive effect on the level of teamwork among the students. The students considered Samuela to be fulfilling a role of a friendly teacher. In general they treated her politely and respected her authority without being intimidated.

4. CONCLUSION

The experiments described in this paper show the potential of an embodied conversational agent (ECA) to improve the level of collaboration for students using interactive learning games. While our ECA was not found to have any significant impact on the realization of short term learning objectives, the quality of collaboration between children was seen to improve dramatically. Since collaboration is known to improve the achievement of learning objectives in the long term and the ability to work in a team is an important skill in itself, we strongly believe there would be significant benefits to the introduction of intelligent ECAs in collaborative learning environments. Our experiments also showed us that children tended to see an ECA in the role of a friendly teacher and were comfortable communicating with a synthetic character acting in this role. As future work we plan to annotate data from the experiments in order to visualize the dialogue along with indicators of collaboration [8] to facilitate more rigorous analysis. This should help us uncover some of the mechanisms of collaboration between the children assisted by Samuela and contribute toward a more formal interaction strategy for the future implementation in a fully autonomous ECA.

ACKNOWLEDGEMENTS

The authors of this paper would like to acknowledge the help of the following persons whose contributions were crucial in realizing the experiments described in this paper. Firstly, we would like to thank the teachers, students and the parents of students at Escuela Primaria Rural Benito Juárez in Acatlima Oaxaca for participating in and facilitating our experiments and tests. We would also like to thank Carlos Martinez and Mario Moreno for helping us to use the excellent UsaLab facility at the Universidad Tecnológica de la Mixteca. Also at the UTM, we would like to thank Rodolfo Palma Guzman and his team at Encargado de Taller de Metal Mécanica for the design and construction of the adjustable large screen display stands used in the experiments (see figure 1 LHS). Finally, we would like to thank Mari Carmen Rodriguez Gancedo and José Relaño Gil at Telefónica for developing the ECA avatar of Samuela.

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