Let’s Play Along! - A Social Robot for Collaborative and Interactive Learning

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Abstract

This paper presents a development of a social robot which interacts with two students in a collaborative scenario. The robot interaction is characterized by the development of a collaborative strategy which aim is to enhance collaboration on the HRI. The strategy was implemented using a user-driven approach. In order to do this a preliminary study was done, to understand and analyze how students interact with each other in a similar scenario.

Then the proposed solution was implemented and evaluated by performing a study with users. The study consisted on having a robot playing a pedagogical game on a multi-touch table and the evaluation was done by comparing two different types of strategies, the collaborative strategy developed and a non-collaborative one. The results showed a statistically significance in terms of the perception of the intelligence that the users have about the robot and the mutual assistance between the robot and the users. Keywords: Collaboration, Robotic Agent, Collaborative Learning, Strategy, User-Driven Approach

1. Introduction

Education is the field which has been less affected by technology. Students of nowadays have access to a variety of technology but it is used more for entertainment purposes than to pedagogical aspects. This paper implements a solution which combines technology, interaction between peers and entertainment to enhance collaboration and consequently collaborative learning. This concept is defined by Dillenbourg as a “situation in which two or more people learn or attempt to learn something together”[4]. Collaboration is “a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem” [16]. Both works concluded that working in a collaborative manner helped students to reinforce their knowledge. Based on this two concepts the scenario defined aims to create a collaborative environment where three actors are playing a didactic game, already developed, through a multi-touch table and where one of the actors is an embodied agent.

To develop the embodied agent with collaborative skills is was realized a preliminary study where the scenario was tested with three human players, it was done with students to whom the pedagogical game is target to, this way it was possible to perceive and analyze how students interact with each other.

The information obtained from the study was then used by an algorithm which used the treated data and returns a strategy to play in the game, this was designated as the Collaborative Strategy.

A second study was performed, but now as a human-robot interaction scenario. In this situation the third protagonist is a social robot, the humanoid NAO, and the aim of the study is to compare the differences between having a social robot using a collaborative strategy and having a social robot that has no concern for this issue.

The structure of the paper is divided in three main parts: on section 3 it is explained the concept Computer-Supported Collaborative Learning, as well as, the pedagogical game and the multi-touch table as a collaborative tool; section 4 exposes the preliminary study and the way the data was treated; and section 5 is the evaluation of the proposed scenario, which explains how the evaluation was done, quantitatively and qualitatively, and also discusses the statistical results obtained.

2. Background

2.1. Collaborative Learning

Collaborative learning was intensively explored during the 90’s, however there is not a unique definition due to the variety of fields in which the concept is applied. Dillenbourg was one of the researchers who contributed the most for the understanding of the
concept. Although not satisfied with it, he proposed a general definition for it: "'collaborative learning’ is that it is a situation in which two or more people learn or attempt to learn something together"[4]. Following on this, it is important to distinguish collaboration from cooperation [5]. On one hand cooperation is the separation of a task in sub-tasks which will be done individually. On the other hand "collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" [16]. In collaboration, participants engage in a social interaction working together on a common problem.

Researchers tried to analyzed independent variables to see how collaborative learning could become more efficient. However variables influence each other, making it impossible to create situations of cause and effect. Therefore Dillenbourg, proposes to understand the role of each variable instead, as he describes "the 'evolution' of empirical research within three paradigms":

The "Effect" Paradigm, this paradigm tries to respond if collaborative learning is more efficient comparing to working alone. The results obtained have positive results. Nevertheless negative results revealed to have a higher impact to be ignored, such as when a lower achiever is joined with a higher one, the first one can easily become a passive participant.

The "Conditions" Paradigm, collaborative learning can be efficient if it is happening under determined conditions. The condition related with group heterogeneity showed that "The 'zone of proximal development' defines an optimal difference", and the size of the group can be ignored when children from the same class are interacting with each other.

The individual prerequisites are other condition for an effective learning, if a participant development is under a certain level compared with the other group members collaboration is not beneficial. The tasks features according to Vygotskian perspective must include "skill acquisition, joint planning, categorization and memory tasks". From these three conditions it is possible to infer that the task should interact with the development of the learners and the nature of the group.

The "Interactions" Paradigm, this paradigm is composed of two features: explanation and control. The explanation assesses the elaboration of the help given from one member to another. It has a strong positive effect on the explainer, since when one person is forced to explain an example he/she is reinforce the knowledge of the subject. Moderately heterogeneous groups are more likely to perform more explanations during the interaction.

The control of the interaction leads to a more efficient collaboration if the strategy for solving a problem is explicit for all the group members.

The conversational process is important for collaborative learning, as it leads to negotiations and helps mediate troubles. Speech can also allow a shared understanding. Nevertheless, non-verbal actions and gestures can serve as "presentation and acceptance", for instance, presenting a new idea [16].

Collaboration is social interaction and when occurs under the define paradigms can bring positive outcomes in the learning process.

3. Related Work

Collaborative technologies are commonly though as technologies the allow people to interacted with each other by shared information [3] or communicate even if they are not in the same place. They are a mean that enhances collaboration. The present work aims to not only take the advantage of these technologies, but also to introduce an robotic agent which is also a "stakeholder" on the process of collaborating in a team with more than one person.

3.1. Learning through Collaborative Gaming

Computer-Supported Collaborative Learning (CSCL), is a concept which refers to technology that supports collaborative learning by enhancing peer interaction, and facilitating sharing and distribution of knowledge between members. These technologies can be computers remotely connected or other technologies that allow face-to-face interactions [12].

Collaborative learning can enhance the learning process, although it is not a guaranteed methodology. Thus, interaction between peers is the key for better results and there are three categories of interaction which contribute to improve learning: explanation, argumentation/negotiation and mutual regulation[6].

Our scenario is based on a situation of three students playing a pedagogical collaborative game in a multi-touch table.

3.1.1 Pedagogical Game: Enercities

Enercities is a game developed by an UE FP7 project 1. Its theme is sustainability and its aim is to make students aware of our society’s energetic problems. The game consists in building a virtual sustainable city. It was initially developed

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1http://www.enercities.eu/project/
as a single-player game and later adapted to multiplayer by the current EU FP7 EMOTE project \(^2\). The current project, which thus turned it into a collaborative game along with its pedagogical aspect.

Enercities is now a three-player game, where each player has a different role in the game: President, Economist and Environmentalist. All roles have similar options to chose what they want to play, plus one extra option that is unique to each role. Players have to make decisions in order to raise the number of inhabitants and advance to the next level. There are a global and individual punctuation and the players must work together in order to decide what is the best for the city, taking into account both scores. This can enhance the commitment of students to “on going negotiations an continuous update and review of progress and achievement” \(^{[6]}\), creating stronger collaboration and engagement with the situation.

All the players have the same resources to spend: non-renewable resources (oil), energy and money. The first one is not possible to recover, its spending has to be controlled, because when it runs out the game is over. Money and energy can be improved by constructing the right buildings or by improving the ones that are already built. There is also a possibility to implement policies, which can related with taxes or other duties and rights of the citizens. The scores are dependent on the choices made in terms of the management of the available means. The game is played sequentially and in each turn the values are updated.

Since sustainability is part of the program of the 7th and 8th grades of Geography course and the 10th grade of Physics and Chemistry courses of the Portuguese education system, the target audience of this game are students between 13 and 15 years old.

3.1.2 Collaborative technology: Multi-Touch Table

The flexibility and easy use of multi-touch devices makes them an interesting complement to other pedagogical tools. A table, by itself, is an object that allows a social interaction, sharing of ideas and communication between people \(^{[13]}\). Having children working in groups at a table improves collaboration and allows an exchange of knowledge. Using multi-touch tables in a pedagogical scenario, such as a classroom or as a support to students’ study, will surely enhance interest in learning.

According to Rochelle’s theory of convergent conceptual change \(^{[15]}\), (“when two learners work together with a reflective tool, they tend to converge on an understanding that is better than either could achieve independently” \(^{[6]}\). There is also the case when one person knows more information on the subject than the other, so the more skilled one will help the less skilled. This matter is important when elaborating pedagogical scenarios with multi-touch tables. Some studies have focused on the multi-touch table design to improve collaborative activities \(^{[11]}\), as the horizontal surfaces offer significant advantages for interaction and collaboration. However, the pedagogical software used as well as the oriented tasks, have a higher impact on the benefits of the multi-touch device. The software can also help to reduce the problem of free-riders, students that do not participate as much as others.

Another important issue is comparing children working together on a normal table with paper \(^{[10]}\). In this case it is clear that the flexibility of multi-touch tables brings more benefits for the final goal of learning. Although the time of tasks on a multi-touch table were shorter, this was not significant to take into account. The benefits are related to how the multi-touch characteristics allow for an organization and sharing of objects on the table. Not being able to grab objects but being able to zoom them instead leads children to share objects with each other and think aloud, creating more interaction and exchange of ideas between participants. Collaboration is again a highlight, because children tend to interact more with each other while having less dissipation of ideas and more constructive ones, as their attention is more focused on the common goal. The multi-touch table allows more engagement of the group with the tasks.

A common finding from literature research suggests that multi-touch tables allow to better organize ideas in terms of group and individual tasks. Collaboration is strong, because there is more interaction and communication and less individual focused tasks. The objects on the table are spread according to individual and group needs: individual objects are closer to the participant and the rest is set in the middle of the table.

Although the technology is still expensive for real-world application, the development of pedagogical scenarios using multi-touch tables is growing due to the engagement students demonstrate, which improves their study and thus allows for a new learning experience.

4. Preliminary Studies

A preliminary study was done in order to understand the basis of interaction between a group of people when collaborating in a scenario where Enercities is played through a multi-touch table, figure 1. The scenario consisted in having three players placed around the table and having their role in the game randomly attributed.

\(^2\)http://www.emote-project.eu
4.1. Method

The study was done at school Escola Maristas de Lisboa (EML) during two days, and two different conditions were performed using Enercities as a three-player game. The students who participated in the study were previously asked permission to their parents who signed a consent form. A geography teacher was also a participant in the study. The aim of the study is to collect data related with the interaction between players on the collaborative scenario. The performance of the game, in terms of scores, is not considered.

Participants

A sample of 31 children, ages between 13 (8th grade) and 15 (10th), and one geography teacher participated in the study. As the concepts behind Enercities are related with sustainability which are taught on the 7th grade of geography course, we guarantee that students from the 8th grade have some previous knowledge on the subject. As Physics and Chemistry program course of the 10th grade also covers related subjects, teachers suggested that the students from the 10th grade could also participate in the study. Nevertheless, the groups were divided according to students’ age. None of the students who participated in the study had any previous interactions with the game.

Procedure

Each session lasted about 40 minutes and was divided in three planned parts. In the begging of each session a brief live tutorial was done in order to show the features and the aim of the game to the participants.

The next 20 minutes were reserved for the game interaction. Since the performance of the game was not to be considered in this study and it can last for more than half an hour, a fixed duration was established for the interaction. This was told before the game, so the participants did not feel any pressure on achieving the last level in the time they were given. The experimental procedure had two different conditions:

I. **Condition 1.** The game was played with two students and one teacher. The teacher was the president and the other roles were randomly attributed to each student. It is important to reinforce that all roles have the same weight for the performance of the game. The teacher was instructed to play naturally and did not receive any instruction regarding her role as a teacher.

This condition was **performed five times**, four with students from 8th grade and the other one with students from the 10th grade.

II. **Condition 2.** The interaction was done with three students and each role was randomly attributed to each one of them.

This condition was **performed seven times**, two of them with students from the 8th grade and the other five from the 10th grade.

In both conditions all players were positioned according to their role and the interaction was recorded with three cameras directed to each player and for the speech with three individual microphones. The game plays were also being recorded for further analyses.

After the experimental procedure each student answered a written questionnaire concerning their opinion about the game, and a set of questions in a semi-formal interview, where students could give their opinion about robots. In **Condition 1** the teacher also answered a written questionnaire concerning the interaction of each group.

Data Analysis

After observing the interactions during the recording sessions and according to the collaborative learning literature mentioned previously, the verbal argumentation and explanation were crucial for the enhancement of collaboration within a group. Taking this into consideration the measures used to analyze the collected data aimed at registering the type of strategy each player thinks is the best to follow in each turn.

The aim of this analysis is to understand which strategy the participants think fits best given the current game conditions. Since Enercities is a collaborative game, it is common that all players negotiate and discuss what can be done to evolve in the game, independently of who is playing. Sometimes there is an agreement between all group members, but other times some players do not agree with what was decided to play. The decision of which strategy
to follow is based on the values of the game scores and attributes in each game state.

Summarizing, the analysis of the interaction was done as follows:

1. in each turn the game state values were registered, these values consist of money, oil, energy, economist score, environmentalist score, president score, number of inhabitants and level, hereinafter design as attributes, which are continuous;

2. and for the corresponding game state was registered the strategy each player mentioned to be the one to choose, independently of being his/her turn to play. There are four different strategies: S1, is the strategy that supports the economy, S2, the strategy for the environment, S3, the strategy that is focused on the wellbeing of the inhabitants, and SG, the global strategy which concerns with energetic and non-renewable resources issues.

This data was later used to implement a similar scenario in which one of the players is replaced by an autonomous robotic agent.

Discussion

This study was performed to make conclusions on how people collaborate with each other to achieve a common goal. The teachers were the ones who chose the groups of students, they were from the same class and this way it was guaranteed that the heterogeneity of the development between students, of the same group, were not too strong. The interactions sessions with the teacher were decided to use in this project to not only to have more data, this is, more game state combinations, but also to introduce a pedagogical point of view. Although the teacher did not received any instructions to act in a determine manner, she eventually ends up to act as a tutor. From the analysis of the videos the teacher suggests plays and strategies and complements the suggestions with information taught during the classes, but she never forces the students to play. With or without the teacher each group had its own dynamics.

In the beginning of the game, students are focused on the exploration of the available game moves. One interesting observation was that the groups did not worry with the scores when they were above zero, but when a score is closed to zero or below zero, their moves usually are focused on improving the negative result. During the game the team members did not compete with each other, the only situations where the students expressed competitive behaviors were when the passed to the next level and a pop up window shows the individual and global results.

Concerning the behaviors, when the students usually supported their explanation by pointing at the multi-touch table. They did not used that much the multi-touch option, such as, dragging the image, they prefer to extend their arm and incline the body on the direction they want to point. Their gaze, the majority of the interaction, is focused on the table, as they are explaining and exploring their valid options. However, in each turn they tend to look at or point to the person who is going to play, accompanied with verbal expression, as "Is your turn", "It’s you now" or even "Is my turn". As the game flows the interactions between plays tend to get longer, it virtual city is getting greater so there are more information to be considered.

In terms of the strategy there was not a defined pattern line that could be perceived by "human eyes". All the groups used different strategies during the game, some defined a long term strategy and then tried to adapt it in the course of the game, others decided only when in the beginning of each turn. Another interesting observation, concerning the players roles, is that one might think that the player with the president role could be the one to act more as a leader, however, apart from the interaction with the teacher, the majority of the students playing in the president’s role were the less interactive and proactive during the whole interaction.

5. Implementation

The design of the architecture was based on the Thalamus framework [14], this architecture has already an implementation used for another project where some of the components were already implemented. The architecture model is shown on figure 2, where the components and its connections are represented.

5.1. Interactive Game

This component is divided in two components: 1) Enercities Interface where is possible to visu-
alize and select the different options, it is developed on Unity\(^3\). This component has the attributes values of the game state; 2) the component Enercities AI has all the game information, it receives the game state and then chooses the best game moves that improve each of the four strategies that can be followed in the game. These four game moves are then sent to the Gameplay Manager.

**Enercities Gameplay Manager (EGpM)**

This the decision-making component, which receives the game moves selected by Enercities AI and the game state from Enercities, and selects a high-level behavior to send to SKENE and be performed by the agent.

- **The Collaborative Strategy Selector** is part of the Enercities Game-Play Manager and is responsible for processing the data collected from the preliminary study which happens when the EGpM is initiated. First the data is discretized, based on [7] which suggests a discretization criterion for continuous-values attributes. Since the sample is small an unsupervised discretization was done to simplify the program. Then the decision tree is created using Gain Ratio as the attribute selection and the C4.5 algorithm for the tree induction [9].

The reason for this dynamic development is to facilitate future improvements and thereby the Collaborative Strategy Selector is not dependent of this collected data. This component runs in each turn with the updated game state and, according to the tree path and the interval associated with the values of each required attribute, returns the strategy that best suits the given game state. This algorithm and the data collected from the preliminary study allows to have a user-driven approach for the strategy selection.

Based on the strategy defined for the current game state the EGPM verifies whether it is the robot’s turn to play or not. If so, the EGPM selects the game move (previously sent by Enercities AI) that corresponds to the chosen strategy and sends it to Enercities for execution. If it is another player’s turn the EGpM can proceed in two different ways: 1) suggest a specific play, according to the strategy obtained; or 2) suggest only to flow the strategy (for instances, suggesting to help the environmentalist).

**Perception**

is currently used only to track the user’s face, in order for the Skene component to be able to direct the tutor’s Gaze to the players. The tracking is done using a Microsoft\(^\text{R}^\circ\) Kinect\(^\text{R}^\circ\)\(^4\).

**SKENE**

is a component which was developed as a behavior planner for the EMOTE project [14] all the other components are connected to this one. The EGPM sends high-level utterances based on FML that contain both the expressive behavior and the game actions that are to be executed by the tutor, while the Perception module updates the localization of the users (for gazing), and Enercities sends information regarding players’ clicks, and the on-screen location of relevant objects (for gazing and pointing at the screen). This component performs a semi-automated gaze behavior using a gaze state-machine, and manages the scheduling and synchronization of the verbal and non-verbal behaviors contained in the high-level utterances.

The SKENE utterances were extracted from the analysis of the videos of the preliminary study, and then were scripted and categorized.

6. **Results**

To evaluate the proposed implementation two conditions were tested and the main hypothesis of the study was to see if there is a significant statistical difference when using the collaborative strategy selector. The robot NAO played with two participants and Enercities was played in a multi-touch table.

6.1. **Participants**

All the participants were students from Instituto Superior Tecnico, Taguspark Campus, where the study took place. A total of thirty two participants, 15 female and 17 male, with ages ranging from 18 to 28 years old, participated in the study, with eight groups of two people for each condition.

6.2. **Procedure**

Each session was around 40 minutes and in the beginning all the participants had to read and sign a consent form, which allowed them to participate in the study.

The study is divided in two conditions, with eight sessions each:

Condition I, the agent chooses a collaborative strategy using the Collaborative Strategy Selector component, and the agent is playing as the president;

Condition II, in this condition the strategy selected is the one that best improves the score of the agent’s role, which is also the president, as in condition I.

Before starting the interaction, a brief and interactive tutorial was explained, in order to show the goal of the game, the rules and the game moves that users could do, as well as the multi-touch functions.
of the table. Then, the remaining roles were randomly attributed to each participant and according to their role, the players were asked to place themselves around the table. The interaction was about 20 minutes long and ended after the president’s turn, so NAO was the one who notified the participants that the game was finished.

After the interaction, a questionnaire was delivered to all participants, the same questionnaire was used for both conditions.

All sessions were also recorded, video and audio format, for further analyses. The set was composed with three cameras, two of them aimed at the two participants and the third one aimed at NAO. Each participant also had a microphone.

6.3. Measures

Subjective measures were used and supported by a questionnaire, which is divided in three groups. The first two groups are questions that were previously validated and widely used among the Human-Robot Interaction community, GodSpeed Questionnaire[1] and Networked Minds[2]. The third group of the questionnaire has qualitative questions.

6.3.1 GodSpeed Questionnaire - Users’ perception of robots

This questionnaire was designed with the aim of measuring the user’s perception of a service or entertainment robot. Seeing that HRI is multidisciplinary field Bartneck et. al developed this questionnaire in order to give the possibility to technical developers to evaluate their robots. The goal is to standardized a measurement tool for robots that interact with people, since evaluate only their performance, as is commonly done with in industrial robot would leave behind the interactive part of the HRI experience. Based on concepts found on the literature of the field, the questionnaire proposes to evaluate four concepts: animacy, likeability, perceived intelligence and perceived safety.

These concepts can be evaluate separately and for this study four of the five concepts were used:

- **Animacy** is the measure for the "classic perception of live", lifelike creatures can involve users emotionally and consequently influence users;
- **Likeability**, is the measure for the judgment of the first impressions that people do towards a social actor. It is proven that when people have first positive impressions of others it leads them to have a more positive evaluation;
- **Perceived Intelligence**, is the measure for the intelligence of the robot percept by the user. This is dependent on the robot’s competence during the HRI;
- **Perceived Safety**, is a measure which considers the perception of users in terms of the level of danger or comfort during the interaction. Achieving a higher level of perception of safety is a key requirement to accept the robot as a companion or a co-worker, in human environments.

The questionnaire does not evaluate the concepts objectively. Instead it is intended to be used as a tool for comparison. For this case, is used to see if there is a significant difference, between the two conditions, of the concepts mentioned above. It will also allow to compare with other projects that used this tool in their evaluation.

6.3.2 Networked Minds - Evaluation of Social Presence

The agent used in the implementation is intended to be a social actor, thus is important to measure its social presence.

The concept of social presence is no longer seen as the sense of being physically present. Instead, "social presence is the moment-by-moment awareness of the co-presence of another sentient being accompanied by a sense of engagement with the other". In a higher level social presence is characterized by three concepts defined as co-presence, psychological involvement and behavioral engagement:

- **Co-presence** is the degree to which the observer believes he/she is not alone and isolated, their level of peripheral or focal awareness of the other, and their sense of the degree to which the other is peripherally or focaly aware of them. Co-presence is divided in two factors: isolation/aloneness and mutual awareness.

- **Psychological involvement**, is the degree to which the observer allocates focal attention to the other, emphatically senses or responds to the emotional states of the other, and believes that he/she has insight into the intentions, motivation, and thoughts of the other. Psychological involvement is composed by three factors: mutual attention, empathy and mutual understanding.

- **Behavior engagement**, is the degree to which the observer believes his/her actions are interdependent, connected to, or responsive to the other and the perceived responsiveness of the other to the observer’s actions. The factors that belong to behavior engagement are: behavioral interaction, mutual assistance and dependent action.
6.4. Results
This was an explanatory study which was done to test the hypothesis defined through the literature review of the subject in appreciation. The quantitative data acquired through the questionnaires was analyzed with statistic tests, using the SPSS Program \(^5\).

The statistic model used was the analysis of variance (ANOVA), which compares means of different groups and verifies if their means are equal. This test identifies whether the observed differences on the samples are real, this is, if they are caused by significant differences between samples, or casual, this is, merely caused by the diversity of the sample. Wherefore, this statistical analysis is based on the assumption that chance reflects only small deviations, being the great differences made by real causes.

**The null hypothesis:** \( H_0 \) - The means between the collaborative condition and the non collaborative condition are equal to one another.

**The significance level:** 0.05 - The null hypothesis is rejected for values under this level. This also represents a 95 % of confidence interval.

In table 1, the results obtained of all the used measures are shown and in table 5, are the mean values obtained. The value of each attribute is the mean. The GodSpeed questionnaire the range of the values goes from zero to five (0-5), and for the Networked Minds the range varies between zero and seven (0-7).

Observing the results just two attributes have shown a significance value above the significance. Therefore, the variations between conditions have a reflex statistically significant on the perceived intelligence, from the GodSpeed, and mutual assistance, from the Networked Minds.

6.5. Discussion
This study proposed to compare two different test conditions of a scenario where an embodied agent could play a collaborative game with two users.

From the analysis on the previous section the three of the attributes from the GodSpeed questionnaire, animacy, likeability and perceived safety did not have a statistically significant result that could have lead to a conclusion where the differences between conditions would change the user’s perspective of NAO as a group partner. The means of these attributes were very similar. The attribute, perceived intelligence has a significance value of 0.008 which shows a statistical significance which can be assigned to the changes of the two conditions. On

Table 1: Analysis of Variance - ANOVA

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<th>Sig.</th>
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<td>Within Groups</td>
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Table 2: Mean Values Disaggregated by Condition

\(^5\)http://www-01.ibm.com/software/analytics/spss/
the qualitative information, the majority of the participants who had positive opinions about NAO’s performance, also mentioned that they probably would not have chosen the same play. On the other hand, in condition II the critics were related with technical details that emerged during the interaction. The fact that on condition I NAO proposes game strategies can bring it to a more vulnerable position and hence be subjected to a more critical evaluation.

Although the inconclusive results in terms of the differences between conditions, all the attributes have a mean above three, which is a favorable evaluation for the experience as a whole.

This questionnaire was also developed to compare different HRI experiences. On the Related Work chapter??, some of the presented projects used the GodSpeed questionnaire to evaluate their solutions. For instances, the empathic robot EDDIE which compares three different conditions to analyze if mirrored facial expressions can improve HRI, or not[8]. The first condition is neutral EDDIE does not use any facial expression; second condition, in which the robot mirrors the user’s facial expressions; and, a third condition, where the robot mirrors the user’s facial expression, according to its internal model. Comparing both overall experience the results were very similar. The perceived safety was slightly higher for the neutral condition, the same way it was for the non-collaborative experience. The other attributes obtained almost the same values comparing the two projects. However in the work of Gonsior et al. the neutral condition obtained the lowest values, as opposed to this experience, where the non-collaborative condition showed some unexpected, yet positive, results.

The social ability of the Robot was evaluated through the Networked Minds questionnaire. In terms of co-presence component both isolation/aloneness and mutual awareness presented high values for the observed significance level of the ANOVA test. However, in both factors the two conditions have means above 5 in a range of 7. So the degree to which the participants were focally aware of NAO and the sense that NAO was aware of them is high, regardless the changes between conditions.

The attribute psychological involvement has three factors. The mutual understanding factor, although does not have a statistical significance reflected on the variations between conditions, its significance level was very small in comparison with attention allocation and empathy factors. This attribute evaluates the degree to which the observer allocates focal attention, empathically senses or responds to the emotional states of the other and the observer also believes that has insight into the intentions, motivations and thought of the other. All factors in both conditions have a mean of level four in a range of seven.

At last, the behavioral interdependence attribute one of its factors, mutual assistance, has an observed significance level of 0.029, so the variations between the two conditions have a statistically significant reflex on the results obtained. From the qualitative data recollected, a great number of condition I participants mentioned that the suggestions given by NAO helped them understand the game and progress as they were getting to know the game. On the other hand in the same qualitative question of the other condition, participants referred that NAO could have participate more in the game decisions. The other factors have both high observed significance levels. Behavioral interdependence has a rounded mean of 3 in both conditions and dependent action a round mean of 5 for the collaborative condition and 4 for the non collaborative condition.

The study showed positive results, generally independent from the differences between the two conditions. The qualitative questions illustrated the participants’ acceptability towards the overall experience. This makes us believe that the experience would have success applied in a pedagogical scenario, for example, within a classroom, where the students could consolidate their knowledge, collaborating with their colleagues in an enjoyable manner.

7. Conclusions

The project proposal was to develop a social embodied agent with the ability to collaborate with two students when playing a pedagogical game on a multi-touch table. The game, Enercities, is characterized by having aspects that enhance collaboration, such as, having a common goal and the need to cooperate to evolve in the game. The preliminary study allowed to understand the interaction between the students, how they first discuss what strategy to follow and then play. The information obtained from the study was then collected and treated focusing on the strategies the players wanted to use in each game state.

The collaborative strategy, which uses the analyzed data, is divided in two parts: first, the values need to be discretized and then the algorithm of the C4.5 Decision Tree induces the tree that returns the collaborative strategy during the game.

The results were obtained by comparing this strategy with one that is not collaborative. The last one, the robot just plays, it does not suggests nor uses a collaborative point of view during the game, as it does when uses the collaborative strategy.

The results obtained from the study were very interesting. The fact that the robot interacts more
during the game, in the collaborative condition, by giving opinions of game moves or suggesting strategies, leads it to be more vulnerable to comments, either positive or negative. However the feedback for the whole study was positive, participants enjoyed playing with the robot, mentioning that it was a different and more interactive way to play a game.

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References


