Social Robot as an Awareness Tool to Help Regulate Collaboration

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***Abstract*— In collaborative learning, group awareness is a central issue. Being aware of the group's perceptions allows an adequate regulation of the activity. Our research explores whether a social robot can provide the necessary awareness. This study evaluates the usability and acceptability of a social robot used in such a role. The robot can express emotions and move according to territoriality principles, leading to a novel communication strategy. We designed and evaluated a learning situation where a Cozmo robot is included in a project meeting. As an awareness tool, it moves and expresses specific emotions that represent individual and group feelings to regulate learner communication behaviors.**

I. Introduction

Project-based learning is a powerful method that allows students to learn by concretely implementing concepts studied in the classroom by carrying out projects, most often in groups [1]. Learners organize themselves and coordinate their efforts through meetings that should be as productive as possible. Therefore, they need to learn how to manage these meetings, which is not a trivial task. They must learn to avoid or solve recurring problems: participants having trouble focusing on the main topic, monopolizing the floor or discussing in a sub-group [2].

Group awareness is sometimes provided to collaborators with the help of digital devices that present information about the group's interaction, mainly in the form of dashboards. This information helps learners to self-regulate. However, these tools are not necessarily the most appropriate to communicate emotional information and are mainly designed to be consulted after the work session in order to improve for the next session. Moreover, dashboard are often presented on tablets or computer screens that can be easily ignored in a face-to-face meeting situation. New technology such as social robots could help present rich and easy to understand information during the work session and give to learners the opportunity to correct their behavior in real time.

Our aim is to propose to provide awareness information regarding the general state of mind of the group, leaving the participants with the opportunity to use this information to regulate the group activity. We are especially interested in exploring innovative ways of expressing this awareness. We believe a social robot could be able to express the salient group feelings by simulating emotions. We also wish to take advantage of the territoriality principle to provide additional information on the target of the robot's message. In this paper we present a prototype of awareness system using a social robot and territoriality principles to communicate emotional information during a meeting as well as a study designed to evaluate intelligibility and acceptability of this system.

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II. Related Work

A. Regulating Collaboration for Project-based Learning

As stated by Jermann *et al.* [3], the regulation of collaborative interaction is a four-part process. Data about the interaction are collected, aggregated and used to compare current and desired states of the interaction. Finally, some advice is provided to the learner to improve future interactions. Some regulation systems (*coaching systems*) apply the entirety of the process [4]. Others are only designed to collect, eventually aggregate, data and present them to the users. *Mirroring* or *metacognitive tools* aim to raise awareness on the collaborative situation for students and teachers, leaving them with the opportunity to regulate their actions by themselves.

In awareness systems, data can be collected automatically through the use of sensors installed in the room such as microphones [5]. It is also possible to rely on the learners to provide data to the system [6], especially when the data that needs to be collected is related to the learners' state of mind (goals, thoughts, feelings, etc.).

Data can be presented to the learners in various ways through a variety of devices like interactive tables [5], [7] or screens in the form of a dashboard [6]. Regarding the presentation of emotions or feelings, several methods can be used such as emoticons, plain text [8] or graphical elements [9].

Although those methods can be informative, they are not as rich or intuitive as the emotions expressed by a human being. We also noted that if awareness tools, in general, can be really helpful, they are however mostly designed to be consulted after a work session in order to try to improve for the next session and rarely to allow learners to correct their behavior in real-time. Moreover, they are usually presented on devices such as tablets or computers and can be easily ignored, especially in the context of face-to-face meetings where the focus is usually put on the group discussion and not on the surrounding screens. We believe that an alternative platform to present emotional awareness information could be social robots.

B. Social Robots

Social robots are specifically designed to communicate with humans through channels that are typical of human-

human communication such as voice, emotions or gestures. They are often used in public spaces to interact with people and provide them with information. When interacting with them, humans tend to think they have a form of social intelligence [10].

These robots tend to be more and more used in educational contexts where their social characteristics and embodiment are believed to constitute an advantage [11]. They are even considered as potential regulating tools [12]. We believe that social robots could be a suitable platform for an awareness tool because their embodiment and usual communication channels would allow them to draw attention and easily present emotional awareness information during a collaborative activity. Participants would have an opportunity to regulate their behavior during the work session. They also seem naturally more difficult to ignore than a dashboard displayed on a tablet.

However, social robotics is still an emerging technology. Given their novelty aspect and usually fun appearance, one could think that robots are more likely to distract than to help. Moreover, when compared with traditional dashboards, they are naturally slower to communicate and are only able to present one piece of information at a time. This information is also not persistent because it can not "stay displayed" as on a dashboard. To allow robots to deliver more information and enrich the content of the message, we can take advantage of the territoriality principle.

C. Territoriality

Territoriality is a key concept of tabletop collaborative work and is defined by Scott [13] as the natural division of the collaborative workspace into personal, group and storage territories by the participants. They tend to use personal territories, located directly in front of them, to do their part of the group work and to use group territories, located anywhere but on the personal territories, to perform the main task of the activity. This territoriality concept is useful to design collaborative applications [7] since people tend to look for specific information on specific areas.

This principle could help to build a clearer and richer awareness message for meeting regulation. Indeed, meeting problems can concern different persons or aspects of the meeting (topic, organization of the discussion, etc.). Territoriality could be used to indicate in the message which aspect or person is concerned by linking it to a specific part of the workspace.

D. Hypotheses and Research Questions

Our work aims to conceive a new type of awareness tool to help students self-regulate during a project meeting and, in the long run, learn how to conduct efficient meetings. We make the hypothesis that social robots and territoriality principle can be usefully combined to express significant messages. We could use the ability for social robots to simulate emotions to deliver emotional awareness information. The territoriality principle could also be used to compensate some of the robot's limits like the inability to deliver more than one piece of information at a time. A social robot could, for example, designate the target of a message by moving to a specific area of the table before delivering it by expressing a specific emotion.

This hypothesis induced many questions like what kind of messages must be proposed to students to favor a positive impact on learners behavior and learning? Which areas must be proposed on the table? Is this communication strategy understandable? Is this combination of devices acceptable?

Before evaluating the impact of this new type of tool on learners, we must ensure that our communication strategy is intelligible for the users and whether they are willing to accept this type of system. We chose to use a user-centered method: we implemented a first prototype of the awareness system and organized focus groups with students to determine how to improve the awareness principles and communication strategy.

In the following sections, we present the design principles of our prototype and an experiment done with 28 participants in order to answer the following questions: Is the system relevant for these types of situations? Is the system acceptable for the learners? Is the communication strategy intelligible?

III. System Description

Our system aims to provide awareness about the various feelings of participants in a project meeting, especially the feelings that can be harbored by interactional problems such as people monopolizing the floor or drifting of the discussion topic. The awareness information is provided through a three step process: collecting the data about the meeting, defining the message to communicate to support the self-regulation process and delivering the message to participants.

A. Collecting the Data

The information collected is related to participants' perceptions towards the meeting, especially perceptions that can occur when they are confronted with problems. Those perceptions can be divided into three categories: perceptions related to the meeting in general (*The topic is drifting*, *No one listens to each-other* and *The meeting is not productive*), perceptions related to the behavior of another participant (*Someone is monopolizing the floor*) and perceptions directly related to the persons needs (*I am bored* and *I want to speak*). Those perceptions were chosen by considering the problems that commonly occur during a meeting [2]: participants having trouble to focus on the main topic, monopolizing the floor or discussing in a sub-group of participants.

We chose to let students self-report their perceptions because it helps the building of metacognitive abilities, and the automatic detection of those inner thoughts through the exchanges between participants seem extremely complex to achieve. The information is then collected through tablets: the participants can express six different perceptions about the meeting: *I am bored, I want to speak, The topic is drifting, Someone is monopolizing the floor, The meeting is not productive* and *No one listens to each other* with the help of six buttons displayed on the screen. Moreover, when clicking on the *Someone is monopolizing the floor button*, participant will be asked to name another user. Every click on a button provides the system with data to be presented to all the participants.

B. Building Awareness Messages

Messages delivered by the system are built by associating one emotion to express the valence of the message and one area on the workspace to point to the target of the message. We selected four different emotions that we believe can be associated with the various perceptions the participants can express: *anger* when the meeting is considered as not productive or when someone is monopolizing the floor, *confusion* when the topic is drifting or no one listens to each other, *enthusiasm* when someone want to speak and *boredom* when someone, or the group, is bored. Four areas were selected as well according to the meeting aspects that can be targeted by the messages: *personal*, *meeting*, *topic* and *discussion*. The areas are distributed on the meeting table accordingly to territoriality principle: personal areas are located in front of participants and group areas are located in the center of the table. By combining emotions and areas, we defined 7 different messages to help the meeting regulation (see Fig. 1). For example, if many participants declare that the topic of the discussion is drifting, the system will build a message combining the *confusion* emotion and the *topic* area.

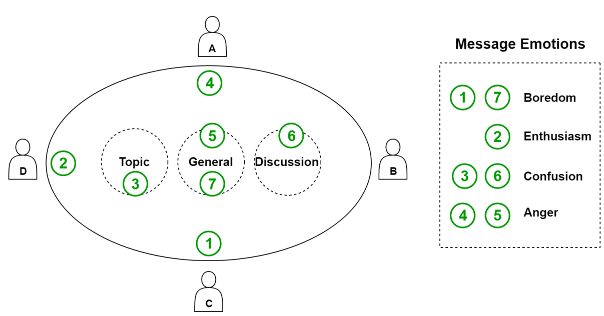

Fig. 1. Messages composition and distribution over the meeting table

The messages to communicate are selected based on the number of clicks made on each button of the tablets during a given period. Some messages only need one click to be triggered, others require that the number reach a specific threshold. The chosen messages are stored in a queue and delivered one after the other.

C. Expressing the Messages

We chose to use the Anki social robot, Cozmo[1], to present the information to the meeting participants because it is designed to be able to express a large range of emotions vividly. It is also small and able to move easily in the multiple areas present on the table.

During the meeting, participants are gathered around the table where we place one Cozmo robot and where the central areas are materialized through labels (see Fig. 2).

Fig. 2. Layout of the meeting table

For each message it has to communicate, the robot moves to the associated area and uses an animation to express the associated emotion. If the robot has to express the *confusion/topic* message, it will move physically towards the *topic* area before playing the *confusion* animation.

Beside moving to the area associated to the message, the robot will get into position in order for the animation to be seen by the concerned participants. For example, if the robot has to express the personal message associated with the *Someone is monopolizing the floor* perception, it will play the animation while facing the designated participant. However, when the robot expresses personal messages associated with personal perceptions (*I am bored, I want to speak*), it first turns to face the other participants. When expressing a group message, the robot randomly choose a participant to face before playing the animation.

IV. Study

This study aims to evaluate both the acceptability of the system for students and the intelligibility of the communication strategy used to present the awareness information. We conducted several focus groups in which participants took part in a short demonstration of our system before discussing it as a group.

A. Focus Group Process

This focus group is a two-step process and was designed to last around one hour. First, participants are driven through 4 distinct scenarios in which they take an active part. They are given a role at the beginning of the experiment and have to press specific buttons for each scenario. Each group experiences the same demonstration.

- **Scenario 1:** Participant A has been monopolizing the floor for several minutes.
- **Scenario 2**: Participants C and D are arguing vividly, refusing to hear each other out.
- **Scenario 3:** Participants A, B, and C are discussing among themselves. Participant D would like to intervene but they are unable to take the floor.
- **Scenario 4:** Participants A and D are discussing a point that only relates to them. Participants B and C are bored.

By enacting these scenarios, participants discover every emotion the robot can express and every type of message that can be conveyed (expressing a group feeling regarding a

[1]www.anki.com/en-us/cozmo

specific person, a specific aspect of the meeting, the meeting in general and expressing a participant's feeling).

Participants then take part in a discussion phase divided into three parts. The first part aims at determining *whether the communication strategy was clear and intuitive enough*. For each scenario, participants were asked to explain their own understanding of the robot's behavior. Questions were then asked about the appropriateness of the chosen emotion and area. The second part of the discussion aims at *evaluating the acceptability of the system*. Participants were asked to write down four advantages and four barriers to the use of this system in a real meeting. Each participant was then asked to explain to the group the advantage and the barrier that was the most important to them. The third part aims at brainstorming collectively about *solving the different problems* mentioned during the previous phase. Cards representing the system components were placed in front of the participants to help construct a broad view of the system and stimulate the creative process.

B. Participants

6 focus groups were conducted in total with 4 or 5 participants in each group. 28 third-year computer science students (27M, 1F), with ages ranging from 20 to 27 years old, took part in our experiment. We chose to work with computer science students because they are confronted daily to project-base learning as the majority of computer science education adopt this form.

C. Data Collection and Analysis

At the end of the demonstration, participants were asked to fill out the french version of the AttrakDiff questionnaire [14] to evaluate the user experience of the system. Questionnaire results have been processed by computing mean scores for each scales of the questionnaire: *Pragmatic Quality*, *Hedonic Quality - Stimulation*, *Hedonic Quality - Identification*, *Attractiveness*.

The discussion part of the focus group was recorded and processed. The answers related to the intelligibility of the system, opinions of the different groups were confronted to identify components that seem to be problematic. Regarding the questions related to the acceptability of the system, answers were also compared among groups in order to have an idea of the general opinion. A thematic analysis [15] was also performed on the advantages and barriers given by the participants to help to highlight the main sources of enthusiasm and concern.

V. Results

This section shows the results of the focus groups: participants' opinions on the intelligibility of the strategy, acceptability of the system and advantages and barriers pointed by the participants.

A. Intelligibility of the Communication Strategy

For the first scenario, every group agreed that the message was clear and understandable and that the robot reaction to the designation of a participant as monopolizing the speaking time was appropriate though sometimes seen as *"too intense"* or *"surprising"*. For the second scenario, the behavior enacted by the robot was understood by most participants. Participants that expressed some doubts regarding this behavior stated that they would not necessarily have chosen the same animation to convey this message. We also noted that participants seemed to have a hard time remembering what the robot did exactly, this could be seen as a sign that the behavior is not naturally associated to the idea they want to express when pressing the button. The third scenario was fully understood and deemed appropriate by 4 groups out of 6. In the other two groups, some participants stated that *"the robot's intention was unclear"*. For the fourth scenario, all participants stated that they understood the message the robot was trying to express and thought it was appropriate. However, this behavior was more complex than the others. The robot indeed expressed first the *boredom* of participant C in front of them and then expressed the *boredom* of both participants C and D in the *general* area of the table. When asked directly if the second part of the robot's behavior was understood, most participants stated that they either did not notice that there were a second part to this behavior or did not exactly understand why the robot repeated the behavior in the *general* area. Out of the 28 participants, only two were able to fully understand why the robot did that. However, when the robot's behavior was explained, they seemed to understand the logic behind it and stated that it was appropriate.

Regarding the division of the table into specific areas, the consensus seems to be that the robot enacting its behavior directly in front of a participant helps to understand that it tries to convey a message directly related to them. However, doubts were expressed regarding the utility of the 3 central areas (*topic, general and discussion*). Indeed, if for some groups, these areas are perceived as useful and help add meaning to the message, some participants did not even notice the labels on the table or that the robot was moving towards specific areas in the middle of the table. The role of these central areas seems less intuitive than for personal areas.

In conclusion, it seems possible for the robot to convey specific messages through its ability to express emotions and the concept of territoriality, even if some elements were not unanimously understood. The 4 emotions expressed by the robot seem to have been understood by most of the participants although *confusion* and *enthusiasm* have raised some doubts. We also noticed that if the meaning of moving in the personal areas was very clear and well received by the participants, it was not the case for the movements in the central areas.

B. Acceptability

The *pragmatic scale* score (0.893) is slightly below 1, this means that even if the participants' opinions are not negative on the matter, improvements can be made to ensure better usability of the system. The *hedonic quality identification* score (1,270) is above 1 but still quite low, meaning that even if the system can be seen as positive regarding the user's identification, progress can still be achieved. This score could be explained by the fact that the participants used the system in a very artificial way through a guided demonstration, thus making difficult for them to evaluate the system relevance in real contexts. The scores for the *hedonic quality stimulation* (1,893) and the *attractiveness* (1,918) scales are both quite high. This means that the system is perceived as exciting, new and also globally pleasant by the participants. In conclusion, even if improvements could be made on some points, particularly on the usability and the identification of the user, the user experience of the system was measured as globally positive. Qualitative analysis will help to understand if improvement must be done on the tablet or the robot.

C. Why or Why Not Use the System ?

TABLE I

Advantages	Count	Barriers	Count
Communication	27	Users' perception	15
Meeting management	17	Distraction	14
Conflict avoidance	11	Perceived limits	8
Captivating	8	Noise	7
Ease of use	8	Logistic	5
Awareness	7	Hard to understand	4
Users' perception	7	Communication	3
Easy to understand	3	Abuse possibility	3
Novelty	2	Loss of time	2
Autonomy	1	App ergonomics	2
Content richness	1	Novelty	2
Visibility	1	Movement	1
Total	93	Total	66

Table I presents the thematic analysis of the advantages and barriers proposed by participants. We noted that they gave more advantages (93) than barriers (66). Most participants mentioned that the system could improve communication within the group, whether because it allowed the shyest participants to contribute more easily or because it *"facilitates opinion sharing"*. It seems that the robot is also deemed useful to facilitate meeting management by many participants by for example helping to *"reframe the meeting"* or *"shorten the length of the meeting"*. Another good point of the system is that it could help avoid the conflict because the participants can express their feelings anonymously. The system is also seen by at least 25% of the participants as captivating, easy to use, fun and able to raise awareness on the state of the meeting.

The two most recurring barriers are related to the participants' perception of the system and that the robot is deemed too distracting. Participants expressed that the robot is too *"childish"* and *"could make the meeting lose its seriousness"*.

Finally, most participants state they would use the system during their project meetings. Some of them add that they would only use it in *"specific contexts, where they would be sure that every meeting participant would welcome the system"*. Participants also seemed to enjoy the demonstration.

VI. Discussion

The focus groups raised numerous issues that must be considered when designing such a system.

A. Collecting the Data

Our awareness system only offers the opportunity for the meeting participants to express negative feelings. However, learners tend to avoid expressing negative emotions [16] even if they feel them. It then seems that only considering problems or negative feelings could hinder the use of our system. Users may also tend to only see the robot as a bearer of bad news and not as a tool designed to help them. Adding the possibility for participants to express positive feelings towards the meeting such as "I agree with you" could help the system to be seen as more positive and even incite participants to share positive feelings.

B. Building Awareness Messages

We noted that some emotions, *anger* and *boredom*, were more easily understood than others, such as *confusion* and *enthusiasm*. As the former are simpler emotions than the latter, a design recommendation that we can give on the use of social robots to convey messages through their ability to express emotions is that simpler emotions will be more easily understood, thus they should be favored.

Participants also expressed that even if the communication strategy is efficient, some points, such as the use of the central areas, are still open to debate. Indeed, at first, several participants did not notice the areas or did not understand that the robot's movement was a part of the message. However, others also expressed that these areas were really useful to understand the conveyed message. This is why we think these central areas should stay within the system but need to be made more understandable. A first step could be to find a way to make them more noticeable.

Some participants mentioned that the robot may be too discreet to handle specific situations such as a larger meeting or a heated discussion and suggested that the robot could make more noise, larger movements of even be more insistent when expressing a problem. However, it seems unwise to us to simply make the robot louder all the time because having a device able to interrupt the meeting by making a lot of noise could be very disruptive of the activity and lead to a negative perception of our system. We could instead try to add a notion of intensity to the message. For this, we could try to take advantage of the vast collection of animation available on the Cozmo platform and simply use more intense variations of the chosen animations to represent this new dimension of the message. However, different variations of an animation can be difficult to distinguish and the indicator may then be difficult to read. Instead of varying animations, this intensity indicator could take the form of an additional device such as the colored lights that are located on the robot's back. The intensity value could be computed by considering the number of users that click on the same button during a short period or the frequency of the expression of specific feelings.

At the beginning of this section, we suggested that giving to the participants the opportunity to share positive feelings could be an interesting addition to our system. However, adding more buttons will require to reconsider the robot's behavior. Indeed, for this first implementation, we tried to choose an appropriate animation for each message the robot had to convey but if we increase the number of messages, we would also need to increase the number of animations and this may require additional efforts for the participants to interpret the robot's behavior. Furthermore, we also stated previously that simple emotions should be favored and there is a limited number of them. We need to find a way to express these multiple different messages with a limited number of simple emotions. We need to conceive a model to classify the messages. We can consider several dimensions such as the target of the message, its time-sensitivity and of course its content (positive or negative, meeting aspect, etc.).

C. *Expressing the Messages*

Participants found the robot too distracting. Most of them explained that this was because the robot was constantly moving, even if it was not supposed to convey a message. To solve this problem, participants suggested that the robot should completely stop moving when it has nothing to do.

However, while working on *adaptor gestures* (i.e. movements performed during idle moments) for robots, Asselborn *et al.* [17] describes an experiment where a robot interacting with young children was seen as more human and more friendly when it was using adaptor gestures. It was also specified that the gestures were not disruptive for the activity.

It then seems that those gestures could be beneficial for social robots as it could make the users have a better perception of them. However, those gestures need to be carefully designed as it seems, as stated by Asselborn *et al.* [17], that an intensity threshold exists beyond which this type of gestures can be harmful to the activity.

VII. Conclusion and Future Work

We investigated how a social robot could be used as a part of an awareness system designed to help students regulate group activities during learning sessions. The robot expresses emotions and applies territoriality principles to represent the state of mind of the group. We conducted focus groups to evaluate the intelligibility of the system's communication strategy and acceptability.

The experiment showed that the system can convey understandable messages even if some elements were not unanimously understood. AttrakDiff questionnaire and direct answers indicate that our system seems to be accepted by the participants. However, participants are computer science students (with a large majority of males) for whom it might be easier to accept new technology. A larger study including a broader variety of participants should be conducted to ensure the generality of the results.

This experiment is a first step in the design of an awareness system using social robots. Next steps are: conducting users centered design experiment to refine both the design of the student expression process and the robot interactive behavior and conducting a larger and longer study focusing on evaluating the impact of our system on students regulation during a meeting as well as on their ability to participate to a meeting in general.

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