The Role that an Educational Robot Plays

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The Role that an Educational Robot Plays

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Abstract— **Human beings naturally assign roles to one another while interacting. *Role assignment* is a way to organize interpersonal encounters and can result in uncertainty decrease when facing a novel interaction with someone we just met, or even to rediscover new roles within previous relationships. When people interact with synthetic characters – such as robots – it seems they also assign roles to these agents, just as they do with humans. Within the field of human-robot interaction (HRI), robots are being developed to fulfill specific roles. This enables researchers to design concrete behaviors that match the desired role that a robot will play in a given task. It would then be expected that if a robot is developed with such a specific role, users too would assign the same role to that robot. In this paper, we study how children assign roles to an educational robot whose role is established from the beginning of the interaction. Our results show that although the role that the robot played was explicitly presented to children, they end up perceiving and assigning different roles for that robot. Moreover, we conclude that role assignment in educational HRI is a dynamic process in which the perceptions of children regarding the robot change over time as a consequence of continuous interactions.**

I. Introduction

Human-robot interaction (HRI) research develops robots for specific purposes, fitting them into particular contexts where they perform well-defined tasks according to some desired role. Since researchers have been designing specific-use robots – contrasting to general-use robots – due to nowadays technological constrains, the advances in this field have become segmented into different areas, such as entertainment, education and assistive robotics. This means that, similarly to humans, robots can play a wide range of social roles according to their intended context of activity.

In the past few years, in the area of educational HRI there has been an undeniable investment in the study of robotic tutors. Indeed, different projects are developing robots for children that can support and assist them during learning acquisitions *e.g.*, CoWriter (`http://chili.epfl.ch/cowriter`) and the EU H2020 L2TOR (`www.l2tor.eu`) projects. In these projects, the robot is designed according to a specific role, such as a *peer*, a *tutor*, or even a *tool* for teachers to use during their classes [1]. To meet the learning purposes of including robots in educational settings, they must be deployed and studied within their main context of use, *i.e.*, schools and kindergartens, in order to interact with its end-users – students and teachers. Despite some research on robots in schools exists, there is still much to understand, especially in long-term educational interactions with robots. Additionally, it is known that people behave in predictable ways based on their social roles perception, which means that knowing the role of the other person can help to determine his/her interactions with the environment and vice-versa [2]. If we are to develop robots intended to operate in a school under long periods of time, studying the perception that children have regarding the role of the robot becomes crucial, especially if children are expected to directly interact with it. In this paper, we present a study on the perceptions that children have towards the role of an educational robot, aimed to teach about curricular-related topics, during a period of two months in their school. This work is part of the EU FP7 EMOTE project(`www.emote-project.eu`), aimed at developing robotic tutor with empathic capabilities.

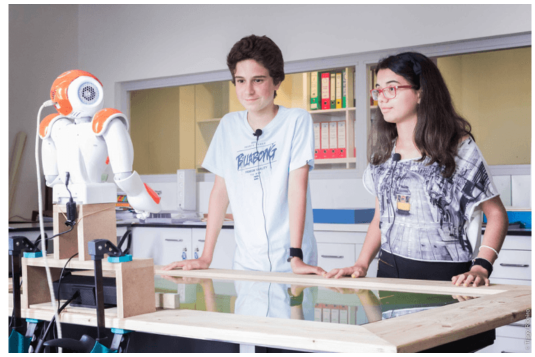

Fig. 1: Setup of our HRI experimental study.

Although the investment in educational robotics is foreseen to continue growing, little is known about the perceptions of children towards the role of a robot that is included in their school environment and intends to assist them in learning acquisitions. In this paper we study not only the roles that children assign to a robot in a short-term interaction (which represents a typical study in the HRI field), but also how role assignment changes over longer periods of interaction time. As such, our research questions can be framed as: *What is the role that children assign to an educational robot that is included in their school? Does the role assignment change with interaction time?* To study this, we have designed and developed an empathic robotic tutor to teach children about sustainable topics in the scope of the EU FP7 EMOTE project [3].

The hypothesis of our study are the following:

1) The role that children assign to a robot will change with interaction time, with children assigning a different role to a robot after the first and last session.
2) The role assigned to the educational robot will vary according to its empathic capabilities.

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II. BACKGROUND

Interacting with others is a inherent part of our lives. The way we face others and position our behavior depends largely on the role we play and on the roles we attribute to others.

A. Roles and Humans

In human relationships, the assignment of a social role can be an abstract process, making role identification a difficult human task even in specific contexts [4]. Interpersonal encounters provide an important context for self-regulation and social judgment due to the inherent exchange of information. Often, however, *"our performance in such encounters are shaped and constrained by the social roles we must play"* [5], making role assignment a non-straightforward task. Indeed, when we draw inferences about someone's role, we often *fail* in this judgment, allowing biasing effects upon performance [5]. This happens mainly because the categories of roles that we define in our minds are abstract nodes of associations that capture and try to organize precise instances and specific individuals [6]. Nonetheless, the process of role assignment is an important one as it helps us to understand each other and make inferences about the characteristics, feelings, behaviors and thoughts of others. In the process of assigning roles, *"we compare a newly encountered person with our own preexisting notions about what other individuals are like"* [7]. This makes role assignment dependent on our own personal experiences and also on previous encounters with others. When we find a match between an exemplar of a particular role category we already had and a new person, we classify that individual as a member of that category [6].

B. Roles and Robots

Nowadays, robots are being designed for a specific use instead of being general-purpose, and currently no robot is able to perform a complex combination of tasks efficiently, accurately and robustly [8]. Moreover, researchers have taken robots as an opportunity to explore how the potentialities of this type of technology can be applied to a variety of different contexts, and therefore develop robots to fit specific roles. When we consider robots being developed to interact with children for learning purposes, it is notable the investment in the design of efficient and engaging ways of integrating robots in school environments in order to motivate students and foster learning. For example, in the CoWriter project, a social robot, playing either the role of a *tutor* or a *facilitator*, is being developed to explore ways to help children with the acquisition and practice of handwriting skills[9]. Studies within this project showed that children successfully engaged with the tutor robot and improved its writing to a level which they were satisfied with, and that children interacting in the presence of a facilitator robot felt more responsible for their peer's performance and learning acquisition.

Zaga et al. [10] investigated whether children engage more in a playful task by having a robot designed to have the role of a *tutor-like* or *peer-like* character. Their results show that children seemed more engaged in the task when the robot acted as a peer-like character and concluded that more research needs to be conducted in order to understand the influence of role assignment in HRI, namely *"if and how a social role can emerge from a social character"* [10].

In order to study what children expected about the interaction with an educational robot that teaches them about prime numbers, Kennedy et al. [11] provided a list of different roles to children and then asked them to assign a role to the robot that they just interacted with. Despite having explained to children that "they were going to be *taught* by a robot *teacher*", results show that children consistently attributed to the educational robot the role of a *friend* after the interaction. Moreover, they found that the robot that expressed adaptive social behavior led to less learning gains when compared to an asocial robot.

Thus, role assignment goes far beyond explicit instructions, and may be related to the time that children have to interact with the robot, or even its social expression repertoire, *e.g.*, voice and gestures. In futuristic classrooms, where robots are likely to appear under similar learning activities as the ones described above, the role that children assign to them as an entity that can learn and as an autonomous agent that can teach, is yet to be discovered. Understanding how children perceive the role of an educational robot can provide insights about their learning process and possibly on their learning outcomes and behavior towards the robot. Moreover, it seems that the different repertoire of behavior in the robot must be concrete enough for children to assign the role to which the robot was developed for. In this paper we present the result of a long-term evaluation study regarding role assignment of children to an autonomous robotic tutor with empathic capabilities. We also studied if *empathy* influences children's role assignment to the robot.

III. EMPATHIC ROBOTIC TUTOR

This section describes the design and development of the empathic robotic tutor used in our study. Fig. 1 illustrates the setup of our experiment, where two children interact with a robotic tutor in the context of the MCEC game, a multiplayer version of a serious game about sustainable city development [12]. Fig. 2 depicts the architecture of the empathic robot tutor used in our learning activity. As we can see, the architecture involves a complex interaction between several modules at run-time, *i.e.*, while the robot interacts with children and the learning activity unfolds.

A. Modules Overview

As can be seen from Fig. 2, the system includes two main modules processing the perceptual input: the *Rapport Manager*, is responsible for automatically regulating the robot's rapport while it interacts with the students. Based on auditory input, it automatically adjusts the robot's speech volume according to the average perceived volume. The idea is to ensure a smooth communication with the users. It also adjusts the robot's head direction, automatically shifting the robot's gaze towards the active speaker to provide a more natural interaction. Finally, it also manages the turn-taking behavior of the robot, interrupting its speech behaviors when

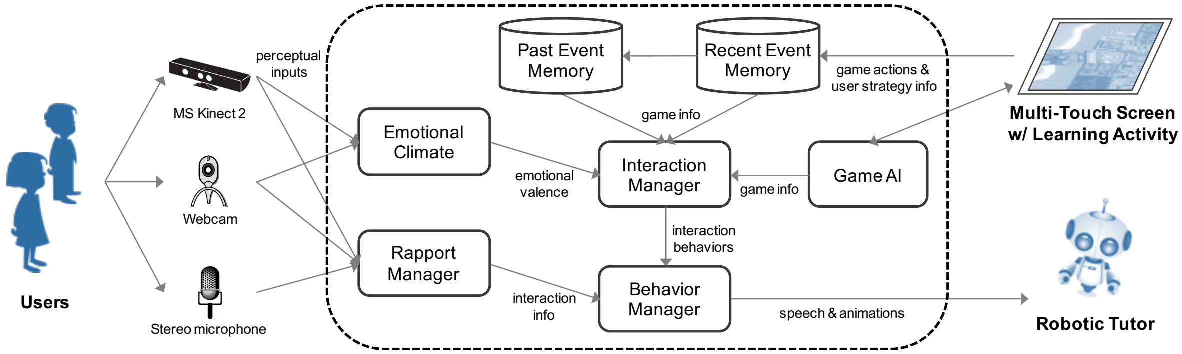

Fig. 2: Overall architecture with the modules of the empathic robotic tutor in the learning activity.

detecting that a user is speaking in a "polite" manner by performing back-channeling behaviors after users' responses. The *Emotional Climate* (EC) module is responsible for detecting the group-level emotional expression at a given time. This module uses machine-learning (ML) techniques to learn models of group EC classifiers based on prior video analysis and annotation of students interacting with a remote-controlled robot during Wizard-of-Oz (WoZ) studies. At run-time, the students' expressive information is combined and fed to a ML model in order to detect the group's current EC valence, being labeled as either *positive* or *negative* (we refer to [13] for more details). The detected EC influences the selection of utterances for the robot during the communication with the users with the purpose of *perceiving* the affective state of the students and *adapting* the pedagogical behavior of the robot to the EC at each time.

Within our architecture, the robot has access to performance information regarding each user that is stored in two different structures: the *Recent Event Memory* stores recent student performance information collected directly from the learning activity engine. The robotic tutor sometimes uses this information to act in a pedagogical manner, *e.g.*, by showing its support regarding the users' difficulties in the learning activity. As children interacted with the robot for two months in four different sessions, the information of recent events is passed to the *Past Event Memory* and used at the end of each learning session by the tutor to wrap-up the activities and summarize the main results achieved.

The *Game AI* module, as its name indicates, is responsible for managing all the actions of the robot in the learning activity by also communicating with the activity's engine. Its social component is able to learn the strategies being used by the students during the learning session and its planning component generates possible actions according to the current state of the activity. In this manner, our robotic tutor is able to act empathically within the learning activity by using pedagogical strategies and contingency behaviors, as well as adapting this to their difficulty level in a personalized learning approach [12].

Regarding the interaction behavior of the robotic tutor, the *Interaction Manager* is responsible to generate behavioral content at run-time according to information regarding the EC and events happening within the learning activity, as depicted in Fig. 2. Within this module, a *rule-based component* automatically triggers pedagogical behaviors based on specific, well-defined detection rules, *i.e.*, in response to specific events occurring in the activity. On the other hand, a *ML-based component* activates social and pedagogical behaviors according to the output of a classifier that informs the system of interesting opportunities for the robot to intervene. This more flexible component is learned offline after several WoZ sessions and tries to mimic the pedagogical strategy that the experts employed when remotely-controlling the robot (more information on this module can be found in [14]).

An example of an implemented pedagogical behavior of the robot concerns the adaptation to children's learning difficulties. So, if the learning activity is in the beginning and a child is taking to much time to play in the game, the robotic tutor would say *"Try to click on the menu near you to see the different options that you have to make our city more sustainable."* In this case, the robotic tutor would provide specific game rules for the child because it would infer that the learner does not know what to do in the early stages of the activity. However, if the same situation occurs near the middle of the activity, the robot would say *"There is no problem when we take some more time to think about the different options that we have for our city."* This change is then contingent with the progress within the activity, as the robot infers that the child already knows the game rules and will thus reinforce the importance of reflection towards choices about sustainability [15]. Regarding to the influence of EC in the expressive behavior of the robot, an example when perceiving a positive EC is: *"Sometimes it is not easy to understand what to do, but taking some time to think seems like a good option."*. In this case, the robot provides to the children a safe place to think about learning contents. On the other hand, the robotic tutor reformulates its scaffolding strategies when facing a similar situation while perceiving a negative EC: *"Sometimes it is not easy to understand what to do, but let me help you with that."* In this case, the robotic tutor proceeds with elaborations about sustainability that can help children during the game.

Finally, the realization of the robot's behavior in the external environment is carried out by the *Behavior Manager*, that translates all interaction behaviors into animations and speech reproducible by the robot's low-level control engine, according to information arriving from the Rapport Manager. It is also able to perform basic idle, non-verbal animations

TABLE I: Overview of activation of all robot modules according to each condition. See text for details.

Module	Description	Activated	
		Empathy	No-Empathy
Recent Event Memory	Recent activity events.	Yes	Yes
Past Event Memory	Specific past events and task summaries.	Yes	No
Behavior Manager	Automatic idle, verbal and non-verbal behaviors and sounds.	Yes	Partially
Game-AI	Game-playing, strategic AI for MCEC.	Yes	Yes
Rapport Manager	Automatic adjustment of gaze, speech volume and turn-taking according to users' speech.	Yes	No
Emotional Climate	Automatic modulation of behavior according to perceived group emotional climate.	Yes	No
Interaction Manager	Social and pedagogical interaction behaviors based on detection rules and ML strategies.	Yes	Partially

and reproduce sounds contingent with the robot's intended behavior in order for the robot to appear more "alive" and aware of its surroundings.

B. Module Differences in Study Conditions

Table I gives a brief description of each module and whether it is fully (de)activated or partially activated in each of the conditions of our study, *i.e.*, Empathy and No-Empathy. The modules that were deactivated concern perceptions of cognitive and emotional states of children. Therefore, when the empathic modules are off, the robot becomes unable to perceive children's states and as a consequence, it does not exhibit contingency behaviors towards them. It does still have social and pedagogical behavior.

As we can see, only the Recent Event Memory and the Game AI modules are fully activated in both conditions, meaning that the robot is not able to recall past events and summarize activities in the No-Empathy condition. Moreover, the Behavior Manager is only partially-activated, since no sounds are reproduced along with its animations—nevertheless, the basic idle behavior, animations and speech capabilities remain intact. In addition, within the Interaction Manager, only the rule-based component is activated and with a constrained set of rules. This means that there are no behaviors being triggered by the ML-based component in the No-Empathy condition. The Rapport Manager is also activated only in the Empathy condition, meaning that the robot will appear less aware of the students during the No-Empathy interactions. As expected, the EC module is also deactivated in that condition since it is a mechanism that analyses the group's emotional status, thus making the robot less contingent regarding the students.

The overall idea behind our choice is to provide the robot in the No-Empathy condition with the basic skills to correctly act during the learning activity and interact with the students with a minimal set of behaviors. Furthermore, we deactivated only the modules that make the tutor aware of (and appropriately respond to) the student's emotional and expressive state, along with more socially-aware behaviors provided through rapport. Moreover, we refined these two conditions with formative evaluations with four children.

IV. STUDY

The goal of our study was to analyze the role that children assigned to an educational robot after one or several interpersonal encounters with the same robot. To study this, pairs of children interacted with an educational robot in a classroom of their school (see Fig. 1) and at the end of the interaction, they were asked to assign a role to the robot they had been interacting with. Each pair of children was allocated in one of the following conditions:

C1: Short interaction with an empathic robot: Pairs of children interacted with a robot endowed with empathic capabilities, thus belonging to the Empathy condition. They interacted only once with the robot, resembling a typical study in the HRI field;

C2: Short interaction with a non-empathic robot: This No-Empathy condition is similar to the previous one, however, here the robot's empathic capabilities were turned-off (see Section III-B for further details).

C3: Long interaction with a Empathy robot: In this condition, pairs of children interact with the educational robot endowed with empathic capabilities for an extended period of time. This condition is the same as C1, however, instead of a one-time interpersonal encounter with the educational robot, children interacted for a period of two months with the robot, in a weekly session regime. The importance of this difference is related with the instructions provided to children, *i.e.*, , in C1 it was explained they would be interacting only once with the robot, while in this condition they knew it would be for two months.

A. Participants

A total of 52 children participated in this study (*M*=13.67; *SD*=.712 years old; 33 male) with 18 participants in C1 and C2, and 16 in C3. The school teachers grouped children in pairs according to their learning level and interaction preferences. Thus, the interaction with the robotic tutor always occurred in a group of three (two children *plus* the robot). Each pair of children was randomly allocated to one of the study conditions. Due to technical problems, one session was excluded from analysis. Only children whose parents provided written informed consent participated in the study. Moreover, before enrolling into the sessions with the robot, children were asked if they wanted to participate. All of the children assented to participate. This study was performed attending to the guidelines of the Declaration of Helsinki and the standards of the American Psychological Association. Moreover, this study attended to other ethical guidelines for Human-Robot Interaction (HRI) studies and long-term interactions between children and robots [16].

B. Robot and the Learning Activity

Pairs of children interacted with the torso version of the NAO robot (`www.ald.softbankrobotics.com/en/cool-robots/nao`). They had weekly sessions together in a school classroom and the interaction lasted about 30 minutes. During this time, they played a serious game about

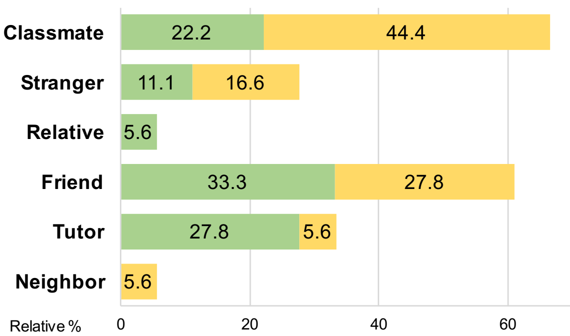

Fig. 3: Comparison of role assignment between the first session (green bars) and the last session (yellow bars) of the long-term study. Values indicate relative % within condition.

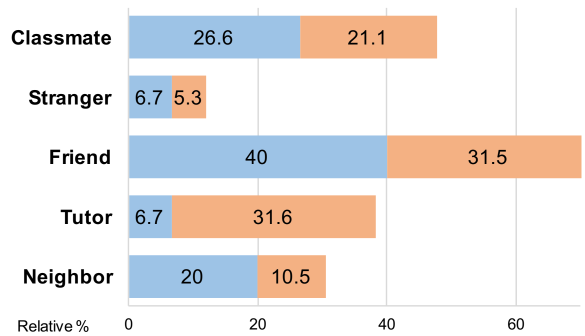

Fig. 4: Comparison of role assignment between Empathy (blue bars) and No-Empathy (orange bars) conditions of the short-term study. Values indicate relative % within condition.

sustainable development, whose goal was to collaboratively create a sustainable city. Sustainable learning involves exchange of perspectives and trade-off awareness in order to conceive a decision that benefit the city [17]. Thus, the role of empathy and contingent behavior becomes especially important in this curricular topic.

C. Procedures and Measures

To measure the role that children assigned to the educational robot, we used the same measure as Kennedy et al. [11]. In this measure, children are asked to assign a role to the robot they just interacted with. Different roles are provided so that children can chose one from eight roles: *brother or sister*; *classmate*; *stranger*; *relative* (*e.g.*, , cousin or aunt); *friend*; *parent*; *tutor*; and *neighbor*. Similarly to what Kennedy et al. (2015) did, children were instructed in all the study conditions that they would be *"interacting with a robotic-tutor that will teach and help them to understand about sustainability topics"*. The role is thus established and explicitly explained to children by the researcher beforehand. For C1 and C2, this questionnaire was applied at the end of the interaction. For C3, it was applied after one interaction with the robotic tutor and also after two months of interaction, in order to compare the roles that children assigned according to their interaction time with the robot.

V. Results

Our results show the role that children assigned to the robot. In Section V-A, we will describe how the assignment of a role changed over time by comparing the role that children assigned in the first session with the last session; in Section V-B, we will present the results of a short-term interaction in which children assigned a role to a robotic tutor with different empathic capabilities.

A. Role Assignment in Long-term Interactions with an Educational Robot

We analyzed if there were differences between the first session and the last session regarding the assignment of the role of *a tutor* by children to the robot. We run an exact McNemar's test and did not find a statistically significant difference in the assignment of the role of a tutor, nor the other roles, comparing the two moments of interaction (*sig.*=.125). Thus, our first study hypothesis was not confirmed. We then run Chi-Square Goodness-of-Fit test to analyze the distribution of roles assigned by children only after the first interaction with the robotic-tutor. The test revealed that, despite being told that they would interact with a robotic-tutor, the proportion of children that assigned other roles for the robot was statistically significantly higher than the proportion of children that assigned the role of a tutor to the robot, $\chi^2(1)$=3.556, *sig.*=.05 (see Fig. 3, in which 27.8% attributed the role of a tutor, contrasting with 72.2% that attributed other roles for the robot). As the majority of children considered other roles for the robot, we thus analyzed what types of roles they assigned to it. From Fig. 3, we can see that after one interaction with the robot, children considered it more as a friend (33.3%) or classmate (22.2%), reporting also alternative roles for the educational robot, such as the role of a stranger (11.1%) or of a relative (5.6%). When analyzing the roles that children assigned to the robot in the last session of the long-term interaction, we can see that the proportion of children that assigned the role of a tutor to the robot decreased (from 27.8% to 5.6%), resulting in an increase in the assignment of other roles to that same robot. Again, the difference in the proportion of children that assigned the role of a tutor is statistically significantly different from the assignment of other roles for the last session of interaction with the robot, $\chi^2(1)$=14.222, *sig.* <.001 (see Fig. 3, in which 5.6% attributed the role of a tutor, while 94.4% assigned other roles for the robot). Thus, children increased their perception of the robot as a classmate (44.4%) and slightly increased their perception as a stranger (16.7%), but decreased their perception of the robot as a friend (27.8%), and refrained from considering it as a relative; instead, they perceived it more as a neighbor (5.6%).

B. Role Assignment according to Empathic Capabilities of an Educational Robot

We run a Fisher's Exact Test that did not show statistically significant differences in role assignment across conditions, *sig.*=.104 (see Fig. 4). This suggests that the role assigned to the robot was independent of its empathic capabilities and henceforth, our second study hypothesis was not confirmed.

Additionally, we run a Chi-Square Goodness-of-Fit Test, showing that the proportion of other roles attributed to the robot is statistically significantly higher when compared to the role of a tutor attributed to the robot, $\chi^2(1)$=11.267, *sig.*=.01 and $\chi^2(1)$=2.579, *sig.*=.108, for Empathy and No-Empathy conditions, respectively (see Fig. 4). Indeed, only 6.7% of children in the Empathy condition and 31.6% in the No-Empathy condition assigned the role of a tutor to the robot, contrasting with the assignment of other roles (93.3% and 68.4% for Empathy and No-empathy conditions, respectively). For the Empathy condition, the majority of children attributed the role of a friend (40.0%), classmate (26.7%), neighbor (20.0%) and some considered it a stranger (6.7%). For the No-Empathy condition, children perceived the robot as a friend (31.6%), classmate (21.1%), neighbor (10.5%) and stranger (5.3%) (see Fig. 4).

VI. Discussion and Conclusions

The results in this paper show that role assignment depends on much more than an explicit instruction. In particular, we found that children perceived an educational robotic tutor to have other roles besides that of a tutor. The only exception is in the No-Empathy condition in which children considered more the role of tutor for the robot. Although this result may seem unexpected, it is in line with what other researchers observed [11], possibly because robots are being developed to behave as teachers but lack an authoritarian appearance and other associated qualities. In the case of our study where we used the NAO robot that has a friendly and child-like embodiment, children may not perceive it as a tutor because tutors are usually adults to which children conceive some degree of authority.

Regarding the other roles that children conceived for the robot, our study shows that they assigned the role of a friend in all conditions. The only exception occurs after two months of interaction with it, in which children shift their opinion and assigned the robot the role of a classmate. This result is probably connected with the novelty effect of this technology. Indeed, by providing children with an opportunity to interact with a robot in a learning environment, children become overwhelmed with the novelty of the interaction and probably project friendly qualities in the robot. After two months of interaction, and having tried to be its friend by talking and approaching the robot, they then realize that the robot is there to teach and help them, but that it cannot answer to more than curricular topics.

Roles are not perceived the same way by people, even if there is a clear instruction that disambiguate the role of a robot in a given task at a given moment. Assigning roles goes far beyond instruction to relate with previous personal experiences and expectations [6]. The results of this paper provide initial clues to robot designers on how to parameterize robots so that their role can be perceived according to some intended manner by its users. We have also demonstrated that the perception of *the role that an educational robotic plays* changes over time. This also suggests implications for the design and development of robots that are able to continuously perceive and adapt to changes in the relationship with its users. In the future, we will perform studies in order to understand the perception of roles in cross-cultural conditions as roles deeply depend on cultural factors. Also, it is important to study if role assignment is related with users' performance in the activity and whether the role perception is influenced by any pair or group effect.

Acknowledgments

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