Evaluating Peer Versus Teacher Robot within Educational Scenario of Learning Programming.

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***Abstract*—This research explores the concept of edutainment where the basics of programming are introduced to children while playing a game with a social humanoid robot. The goal of the game is to exit the maze: the child is asked by the robot to make it walk through the maze to its exit. The child needs to learn the basics of programming through the game via drag-and-drop instructions on the tablet screen. This paper presents an HRI study which aims to investigate which role of the robot (peer vs. teacher) would result in more learning gains in this particular application. The findings suggest that children complete the task much quicker with the peer robot while a teacher robot is shown to be more effective for learning.**

I. Introduction

The research where social robots facilitate educational benefits is an emerging area of social robotics. Recent efforts on the role of robots in educational applications have seen social robots acting as tutors [1], learners [2], and learning companions [3]. In contrast, to date majority of educational robots used to introduce children to programming are mobile small educational robots such as Lego NXT Mindstorms [4] and Thymio [5]. This research addresses this issue with the goal to explore the use of social robots for introducing children to the basics of programming. This paper presents our HRI system which consists of a humanoid robot NAO and an android-based tablet with a drag-and-drop interface inspired by Scratch developed at MIT [6]. The research question of the HRI study is to investigate the role of a social robot which will facilitate engaging and effective learning of the programming basics.

In order to establish social and bonding relationships with children in public populated environments such as hospitals or educational institutions, robots need to be able to adapt to child's needs, so that educational robot is the most productive: robot is liked and accepted, provides comfort and companionship, perceived to be a friend or a peer. We would like to address and investigate this challenge by offering the child such educational robot that acts as a peer rather than a tutor which might potentially ease and relax the child for better and more efficient learning.

Zaga *et. al.* [3] (2015) investigated the effect of robot's social character on children's task engagement suggesting that children solved the puzzles quicker and better in the peer condition in comparison to the tutor character condition. Based on this finding, we hypothesize that children will tend to learn more and quicker in a peer condition since peer robot would be more effective at engaging the child in a task in comparison to the teacher robot who "instructs" rather than engages in play.

Kanda *et. al.* in [7] used a social robot as a teaching assistant to predict whether the social behavior of the robot was responsible for establishing a better relationship with children and whether children were motivated to achieve more with the robot that exhibits social behavior. Social behavior of the robot received better social acceptance suggesting that the social behavior might be useful for motivating children to use the robot to study less engaging subjects. The findings of both Kanda *et. al.* [7] and Kennedy *et. al.* [1] demonstrated that the effect of the social attitude of the robot on children's learning efficiency was not significant.

Shin *et. al.* performed analysis of data gathered from interviews of 85 students to understand student's motivation to learn about robots, to learn from robots, and to learn with them [8]. The authors argue that younger generations generally demonstrated more eagerness to learn about robots rather than high school children and that children of all age did not mind learning from robots, though the robots were not regarded as teachers. Surprisingly, the participants of the *learning from robots* survey noted that the teacher robot was lacking "emotions" i.e., the ability to communicate, care and understand. Moreover, students avoided interacting with peer robots unless these robots acted as teaching assistants (helped to solve homework problems to get better grades at school). The authors also observed that when learning with robots, the robot was viewed more as a competitor rather than a companion.

Up to this end we have been exploring different approaches for educational robots. Our earlier work [9] investigated an adaptive strategy the social robot employed as a peer: the robot was programmed to either always win or always lose during a game, which was developed to teach a foreign language (English) to primary school children. The outcome of the research showed that the indicators of learning performance were significantly higher when children played with the always-losing robot. This was explained by the fact that children aged 6-8 years old are mostly egotistical and urge to be winners. They tend to throw tantrums and show the signs of undeveloped tolerance when the opposite happens.

This paper describes a different approach. This time our social robot exploits two different conditions: a peer-like interaction and a teacher-like interaction. The difference between conditions was in wording of the robot's utterances such as greetings, self-introduction, and goodbyes. Verbal content was the only difference manipulated between conditions. The same pre-recorded male voice was used in both conditions.

II. Hypotheses and Robot Conditions

The focus of this research is to determine which educational strategy a social robot should employ to enhance children's learning outcome and to motivate them to study technical subjects. Based on the previous findings of [3], [**?**], [8], we have identified the following hypotheses:

Hypothesis 1: a peer robot will establish a more engaging experience as determined by a quicker task completion time as suggested by [3].

Hypothesis 2: a peer robot will result in more learning gains as determined by demonstration of better results in a post-test as suggested by [3].

Also the following robot conditions were developed:

Peer robot In a peer-robot condition, the robot acts as if he needed help to exit the maze. The robot chooses to speak in a friendly manner, uses the vocabulary very similar to the one often used by peers.

Teacher robot In a teacher-robot condition, the robot initially sets a professional tone to the game. The robot instructs the child to move the robot through the maze. The teacher-robot's vocabulary is very similar to the one generally used in the conversation between a teacher and a student. In addition, the teacher robot is programmed to point out child's mistakes throughout the interaction.

Robot's verbal content, speaking tone and the ability of the teacher robot to point to participant's errors were the only difference between the two conditions. All non-verbal behaviors such as waving, gesticulating, eye gaze and robot's other behaviors were the same across conditions.

III. Scenario

The concept of this research employs the advantage of a social robot that attracts children and is believed to be effective for children's learning. The core of our ongoing study is to determine the strategies that a social robot should use in order to motivate children to learn technical subjects. In the scenario that we implemented, the robot acts as either a teacher or a peer. A child and a robot both engage in a game on the Android tablet. At the beginning of the interaction the NAO robot introduces itself and offers to play the game together, the robot sets the tone for the game. The robot encourages the child to initiate the launching of the application. At the beginning of the game, NAO gives a brief introduction to programming through a step-by-step tutorial. He first asks a child to drag a particular block of code (e.g. the one that makes the robot walk a fixed distance), drop it in the workspace and run the program. A screenshot from the tablet application is shown in Figure **??**screenshot) Depending on the outcome of child's actions the robot either praises the child and performs the action (e.g. walks) or asks to repeat again. The verbal utterances were followed by visual articulations of sadness and happiness.Throughout the interaction, the robot provided children with hints and instructions. Particularly, the robot explained how to construct an algorithm out of basic blocks necessary to arrive to a destination cell. The game continues in the order outlined below until the robot exits the maze:

1) The robot introduces itself to the child and outlines the tasks.
2) Children starts to play the game which was divided into levels of increasing difficulty.
3) When each level is completed, the robot provides further instructions.
4) When three levels are finished, the robot thanks and praises the child on the good job done.

It should be noted that the robot had two types of male voice (professional tone for a teacher robot and a friendlier version for a peer robot). The dialog between the child and the robot was in Russian. At the end of the game a child was supposed to have an idea of *iterations*, *for* and *while loops*, go straight, turn right and turn left *functions*. The sample of the dialogue between a participant and a teacher robot is outlined as follows:

– Hello! I am teacher NAO. Today, I will teach you how to program. We are going to perform a task, where we are going to escape the maze together. During this task you will learn basics of programming. So, let's start! Task number one: you will see various blocks of commands on the tablet with the help of which you will be able to move me to cells of the maze. First, drag the green "Go Forward" block the left sidebar to the right and click the "Run" button.

If a child performs the instructions, but does not succeed, the robot says:

– Error, you took a different block. Find the "Go Forward" green block. Now, try again!

If a child accomplishes a task, the robot praises the child by saying:

– You did a really great job! It was a pleasure to teach you! See you, bye.

In contrast, the conversation between the child and the peer robot is more relaxed as described below:

– Hi! My name is NAO. Today, I want to ask you to help me exit the maze. For that we will need to learn basics of programming. So let's start! On the screen you can see various blocks of commands, which you can drag and drop from left to right and vice versa. For now, try to drag the green "Go Forward" block to the right and press the "Run" button.

If a child performs the instructions, but does not succeed, the robot says:

– I didn't move, there seems to be a problem! Let's try again!

If a child accomplishes a task, the robot praises the child by saying:

– You did a really great job! It was fun! Bye.

Fig. 1. Screenshot from the tablet application

Fig. 2. Experimental Setup

During the experiment we did not experience any major issues with the NAO robot. The robot neither fell, lost communication with the tablet nor needed an intervention from an operator during the experiment itself. There was a minor problem with the robot's motion. The robot often went slightly aside during the walk as opposed to walking straight. We expected that this would cause the robot to walk outside the maze borders, but it never happened as the cells of the maze were big enough. We would suggest that the problem lies in motors of each leg with one leg being more stable than the other.

IV. HRI Study

The experiment was conducted in a primary school with 26 children (12 females and 14 males) aged 9 to 10 years old. Children were randomly assigned to each condition. Each child interacted with one of the robot's conditions: with a peer or a teacher robot. In both conditions children were free to work on their own pace. The game was stopped either by a child voluntarily or after completing three levels. The robot provided appropriate verbal feedback according to the robot condition when children finished each level successfully and when they were unable to construct a correct block of necessary commands to complete it.

The experiment took place during a day in a primary school with children aged 9 to 10 years old. Each child interacted with the robot for approximately 15 minutes. Participants were divided into two equal groups. It was ensured that children were divided into groups according to their study performance. This was done to avoid situations where one group might have a bigger number of children with higher learning skills than the other group. Counterbalancing has also been applied in terms of gender: each group had almost equal number of males and females. One group of children (6 girls, 7 boys) participated in an experiment with the peer robot and another group (6 girls, 7 boys) with the teacher robot. Each group consisted of 4 children with GPA 5 (out of 5), 6 children with GPA 4 and 2 children with GPA 3.

Children were given a brief introduction to the NAO robot before the experiment. During this introductory session children learned what a NAO robot is and were explained that the purpose of the study was to investigate the child-robot interaction. It was highlighted that children would not be graded for anything they do or say. This was done to make children feel relaxed during the experiment [10]. It was also desirable that children did no or minimal interaction with the robot prior the experiment to ensure accurate results [10].

The experiment was conducted in a small classroom with three researchers inside. Each child was invited to the class one by one to avoid distraction. The child stood facing the robot. The robot was placed on the 1.8m x 1.5m sized printed maze banner located on the floor. The experimental setup is depicted in Figure 3. There was a table outside the classroom for conducting pre- and post-tests by a researcher and a child. Before entering the room, the child was asked to take a pre-test to answer a few questions about their age, gender, and mood. Pre-test was taken also to find out if the children knew anything about programming prior to the interaction with the robot. After the pre-test a child was invited to enter the room with the robot. When the interaction finished, each child was given a post-test to answer questions about the interaction and to find out if the child learned any programming after the game. During the post-test the child had to answer couple of programming questions closely related to the game to find out if the child's level of programming improved after the interaction. All answers were recorded. In the end, the first researcher brought the child back to the class and called out the next participant.

The primary units of analysis were questionnaires and their post-interaction performance in the programming exercise. The key measurement taken during the study were the difference in the level of child's programming experience prior and following the interaction with the robot.

A. Measurements

Children were interviewed before and after the interaction with the robot. The measurements were as follows:

Learning. The difference in the level of child's programming experience prior and following the interaction with the robot.

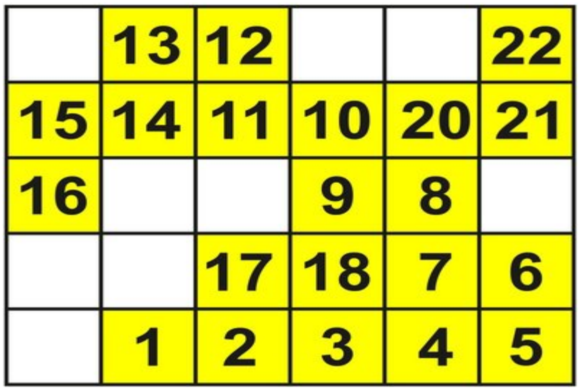

Fig. 3. Maze used for the experiment

MoodChange: pre- and post-mood. Children rated their mood before and after the interaction on a 5-Likert Smiley-ometer scale [21]. We classified the MoodChange as either Decreased, Increased or Same.

RobotLikeLevel. Children rated how much they liked playing with the robot on a 5-Likert Self-Assessment Manikin (SAM) scale.

RobotType. Children were asked to compare the robot to one of the forced-choice descriptors such as Toy, Computer, Pet or Human.

RobotRole. Children were asked to compare the robot to one of the forced-choice descriptors such as Teacher, Friend, Classmate, Sibling, Stranger or Parent.

Funometer. Children used Funometer bar [21] to assess how much they liked the robot.

InteractionComfort. Children were asked to indicate the level of their comfort during the interaction with the robot.

LevelofHelpfulness. Children were asked to indicate if the robot was helpful throughout the game. Was the robot careless, helpful? Did he play an important role or was it a cool add-on, or hindered during the game.

During the post-test children were provided with the smaller copy of the maze and were asked to complete couple of programming questions very similar to the tasks they performed with the robot, for example, they were asked what the robot's next position would be if they dragged the *Go Forward* block to the workspace (given that the robot is now standing at the cell number 1). The picture of the maze can be see on Figure **??**.

V. Results

In general children improved their level of programming as was determined by post-tests. Children who interacted with the teacher robot improved their knowledge of programming a lot better as was determined by comparing results of pre- and post-tests and by a one-way ANOVA ($p = .08$), even though the difference in the learning gain was not statistically significant.

Taking the average, children spent 63.72 seconds interacting with the robot with the standard deviation of 33 seconds. There

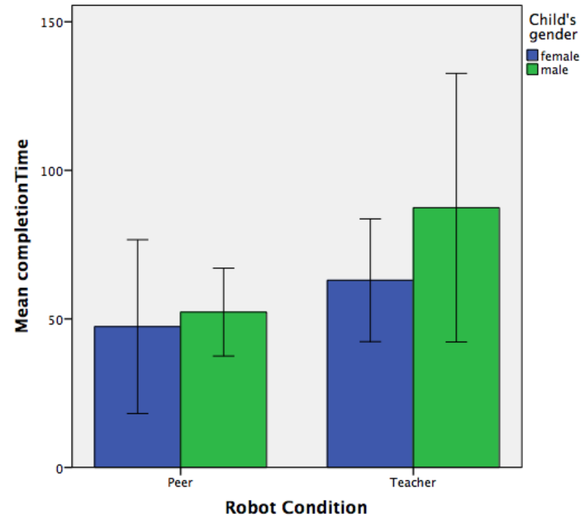

Fig. 4. Completion Time

was a statistically significant difference between groups as determined by one-way ANOVA: $F(1, 23) = 4.373, p = .048$. A Tukey post-hoc test revealed that children spent significantly more time playing in teacher condition (76.15 $\pm$ 38.94 sec) compared to peer condition (50.25 $\pm$ 18.65 sec). The results are depicted on Figure 4

VI. Discussion and Future Work

The goal of this ongoing research is to examine the feasibility of using social humanoid robot to teach children basics of programming. In particular, we wish to explore whether learning performance of children depends on robot's attitude towards them.

The results show that children improved their level of programming after interacting with the teacher robot, though the learning results were not statistically significant. However, there was a significant difference in the time children spent with the robot: as compared with the peer robot, the teacher robot occupied a child for a longer period of time.

Though there was no significant difference in the level of learning outcome between two conditions, children demonstrated slightly higher post-test scores with the teacher-robot condition. These results contradict our belief that children gain more knowledge when interacting with the peer robot. We assume that this was due to that teacher-robot was pointing out errors during the game. As a result, children took the task more seriously.

We also believe that culture might have an effect on how children learn. Geert Hofstede [11] defines the term "culture" as "collective programming of mind that distinguished the members of one group or category of people from others". The social psychologist and his followers [12] argue that every society is represented by a certain set of fundamental values, and these values influence the educational system and the way children are brought up. Hofstede's research on cross-cultural differences in education and learning was not extended on our country in particular, therefore, scores of Russia will be taken into account as it is the only post-Soviet country in the Hofstede's list of scored countries. According to Hofstede's and his followers' set of criteria [12] and their implications on teaching, education in Russia is more teacher-centered and children expect the teacher to initiate communication and provide instructions. Parents have taught their children to never question teacher's authority, as a result students rarely criticize and contradict the teacher. The same tendency is noticed in such countries as Poland, China, Japan, South Korea, Belgium, Singapore and Slovakia.

Additionally, in these countries, students feel more comfortable in structured situations, where a teacher gives precise instructions, detailed assignments and sets strict deadlines. As a consequence, students are rewarded for being accurate and are encouraged to give only solutions out of what they have been already taught. According to this framework, our country, as being the former Soviet country, try not to violate rules set by the teacher. In contrast, in countries including Ireland, UK and USA and most of the European countries the learning performance is taken as a function of two-way communication, a student is encouraged to find their own way of doing things, it is allowed for the teacher to not know answers to some questions. However, most countries, excluding Ireland, UK, USA, China, Singapore, Denmark, Canada and New Zealand, avoid uncertain and unstructured instructions, expecting that teacher knows answers to all questions.

That is why, probably, the results of our experiment contradict the hypothesis proven to hold in other countries [3]. And it would probably have more sense if cultural differences were taken into consideration when choosing between different social robot conditions (e.g. teacher robot vs peer robot, always-winning robot vs always-losing robot).

Vygotsky [13] argues that child's cognitive development is shaped in accordance with the culture and the environment in which the child has grown up. He also emphasizes the importance of guided learning where children and their more knowledgeable partners build up knowledge together. This could explain why children in our experiment did not benefit a lot when interacting with the peer robot as they view the robot as being an equal companion, as a result, the robot was not considered as something that possesses more expertise. In fact, according to [14], for learning language a robot that employs a tutoring approach and social interaction was preferred, while for learning technical and exact subjects the approach of the social robot has not been explored much, some believe that it may not be essential. It is also has been mentioned in [8] that younger children preferred social peer robots in learning while older children viewed robots as teaching helpers.

The above arguments could also explain why children spent more time with the teacher-robot. Children probably spent more time thinking in order to receive praise from the teacher robot, and paid less attention to detail when interacting with the peer robot as they believed that they would not be "punished" by a friend.

Thus, we suggest to further investigate the role of the educational social robot across different cultures. In fact, this research could become one of the pioneering ones in the field. Up to this time, we did not expect that culture might have serious implications on teaching and learning with robots. As a consequence, for learning to become more productive, we need to identify the attitude that the robot should show towards the child (teacher/peer) in different cultures and the strategy it should employ (winning/losing) in places where a peer robot is more effective.

VII. Conclusion

The conducted study compared two robot conditions in their ability to contribute to children's learning of programming basics. Children were suggested to help the robot to exit the maze via drag-and-drop android tablet interface which was inspired by Scratch [6]. Our findings suggest that with the peer robot children completed the required task significantly quicker than with the teacher robot condition. In contrast, children learned more with the teacher robot than with the peer robot. This result contradicts expectations and predictions made based on other studies in the literature [3]. In contrast, our previous study shows that children improved their level of English with the always-losing peer robot in the peer robot scenario. The limitations of both works are in the number of participants in each condition and the need for cross-cultural investigation of acceptance of a social robot as a peer or a teacher. However these works provide strong support for continuing the research direction of investigating robot's role within educational child-robot interaction which is important to consider in order to increase robot's perceived likeability, acceptance and engagement while still fulfilling the required educational value.

References

[1] J. Kennedy, P. Baxter, and T. Belpaeme, "Can less be more? the impact of robot social behaviour on human learning," in *Proceedings of the 4th International Symposium on New Frontiers in HRI at AISB*, 2015.

[2] D. Hood, S. Lemaignan, and P. Dillenbourg, "When children teach a robot to write: An autonomous teachable humanoid which uses simulated handwriting," in *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, ser. HRI '15. New York, NY, USA: ACM, 2015, pp. 83–90. [Online]. Available: http://doi.acm.org/10.1145/2696454.2696479

[3] C. Zaga, M. Lohse, K. P. Truong, and V. Evers, "The effect of a robot's social character on children task mngagement: peer versus tutor," in *Social Robotics: 7th International Conference, ICSR 2015, Paris, France, October 26-30, 2015 : proceedings*, ser. Lecture notes in computer science, A. Tapus, E. André, J.-C. Martin, F. cois Ferland, and M. Ammi, Eds., vol. 9388. London, UK: Springer, October 2015, pp. 704– 713. [Online]. Available: http://doc.utwente.nl/98720/

[4] "Lego nxt mindstorms," http://www.lego.com/en-us/mindstorms/?domainredir=mindstorms.lego.com, accessed: 20-01-2016.

[5] "Thymio," https://www.thymio.org/, accessed: 20-01-2016.

[6] "Scratch," https://scratch.mit.edu/, accessed: 20-01-2016.

[7] T. Kanda, M. Shimada, and S. Koizumi, "Children learning with a social robot," in *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*. ACM, 2012, pp. 351–358.

[8] N. Shin and S. Kim, "Learning about, from, and with robots: Students' perspectives," in *Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on*. IEEE, 2007, pp. 1040–1045.

[9] K. Balkibekov, S. Meiirbekov, N. Tazhigaliyeva, and A. Sandygulova, "Should robots win or lose? robot's losing playing strategy positively affects child learning," in *The 25th IEEE International Symposium on Robot and Human Interactive Communication*. IEEE, 2016.
[10] C. Clark, *In A Younger Voice: Doing Child-Centered Qualitative Research*, ser. Child Development in Cultural Context Series. Oxford University Press, USA, 2010. [Online]. Available: http://books.google.ie/books?id=HhGQbgqVe9EC
[11] G. Hofstede, "Cultural differences in teaching and learning," *International Journal of intercultural relations*, vol. 10, no. 3, pp. 301–320, 1986.
[12] H. Wursten, C. Jacobs, and E. Magazine, "The impact of culture on education," *The Hofstede Centre, Itim International*, 2013.
[13] S. McLeod, "Lev vygotsky," *Simply Psychology*, 2007.
[14] S. Y. Okita, V. Ng-Thow-Hing, and R. Sarvadevabhatla, "Learning together: Asimo developing an interactive learning partnership with children," in *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium on*. IEEE, 2009, pp. 1125–1130.