Using educational robot and tablet to improve wayfinding in children

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Abstract. Wayfinding is one of the most important skills that children have to learn in order to safely move in the environment. One problem that 6-7-year-old children encounter with wayfinding is changing their point of view to that of another person in different position in the same environment, such as that of a person opposite them whose perspective is turned 180° with respect to their own. Robots could help children in learning this skill, since children can instruct them to move in the environment, in predetermined paths, by starting from a rotated perspective. This study uses three different types of robot (humanoid robot, two types of non-humanoid robots, tablets' robot-application) in order to evaluate how a specific activity (instructing a robot to perform a given route) enhances the wayfinding skills of 227 6-7-year-old children. The research shows that children who performed the wayfinding task with tablet's robot-application improved their performance significantly better compared with those who used the other types of robots.

Keywords: Robot Interaction, Child-Computer Interaction, Mobile Device, Zone of Proximal Development, Socio-Cognitive Conflict, Wayfinding, Robot-In-The-Loop Education, Tablet.

1 Learning with robots

According to Vygotskij [1], humans learn and develop skills within their potential of development called Zone of Proximal Development. This concept represents the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peer [1]. In other words, according to this concept, thanks to an active process of social interaction, children can reach their full development potential. The interaction aspect is important not only in the constructivism, social constructivism, and constructionist theory [2] but also in the social learning theory [3]. According to Bandura [2], children can acquire new knowledge and assimilate new behaviours by observing the actions of others. Even though theories appear similar in their emphasis on the concept of learning from

others and on the importance of "social relations"; the constructivist, social constructivist and constructionist theories, compared to Bandura's one, place more emphasis on the active process of social interaction than in the more simple observation of others. Furthermore, according to Vygotsky [1], as for Piaget [4], social interactions can lead to cognitive conflicts in which knowledge construction develops. Doise and colleagues' studies [5-6, 7] on the role of socio-cognitive conflict, examined in a series of different experimental conditions, have highlighted how conflictual interaction promotes progress. An interaction generate conflict when the participants, that are initially focused in their own view, are leads to coordinate their points of view to solve a task during a problem-solving activity. This is fundamental to produce progress in all partners. For example, in a situation in which two children have to collaborate to reproduce a small village map, if they are facing each other they will have two opposite points of view because the right of one is the left of the other so they will have to coordinate their different points of view in order to solve the task. Doise and Mugny [5, 8] showed that children with little or no experience benefit from their partner's point of view, but they also claimed that the more expert children also benefit from working in pairs, since this allows them to increase their performance capabilities. This can be explained according to Vygotsky's Zone of Proximal Development concept: if the gap between the two levels of development is large, there is more improve margin. Therefore, also the concept of socio-cognitive conflict, that is related to Zone of Proximal Development concept, is crucial in Human-Robot Interactions (HRI).
Starting from these theories, the present study assumes that, during HRI, robots will be able to engage a child in an authentic situation of socio-cognitive conflict and thus enhance a child’s ability, acting inside child's Zone of Proximal Development.

2 Human Robot Interaction and Use of robots in children education

In the last few years HRI is born as a field of study that is dedicated to understanding, designing, and evaluating robotic systems for use by or with humans [9]. One of the hallmarks of HRI is treating the robot as an active means, learning social partner, of supporting children as they perform tasks [9, 11]. The volume of studies on the use of robotics in a variety of areas of human life has increased significantly: from supporting disability to developing skills, from learning how to code the robot’s behaviour to learning a second language [12, 13]. Drawing on this line of research, several studies with preschool and school children focused on child-robot interactions with the aim of involving children in different activities, such as computational thinking tasks [14], creative dance [15, 16] narration [17], as well as tasks on space skills [18]. Therefore, there are evidence that supports the use of robotics as an educational tool. Mubin and colleagues [37] affirm that, in educational settings, a robot can have two different roles, active or passive. On the one hand, robots can be used to facilitate the learning of robotics and computer education (passive role) on the other hand, they could facilitate the learning of non-technical education (active role). The first category deals with learning about robotics itself or the functioning of technology (i.e. how to assemble or program a specific robot). The second category regards non-technical information as in this case the robot is used as social partner to develop specific abilities [20]. In a recent review of the applicability of robotics in education, Mubin and colleagues [37] assume that child-cooperative learning achieves better results than individual knowledge acquisition. Therefore, the use of robots in educational settings, as social learning partners or as tools to assemble or program, can bring benefits in different learning environments. The choice of the most appropriate type of robot or its role depends on the setting and the person who will interact with it. For example, if the goal is merely to instruct the robot to perform a particular action or a sequence of movements, basic and low-cost robots such as Bee/Blue-Bot or Ozobot are recommended. Robots like Nao [21], Pepper [22] and MecWilly [13] are particularly useful in enhancing abilities or acquiring non-technical knowledge such as music, spatial orientation and language [37]. In this regard, starting from the paradigms of the "Robot as Social Partner" and "Robot as Programmable Tool" [37] this paper reports a research project which uses a humanoid robot, two non-humanoid robots and a digital representation of the humanoid robot (tablet application) in order to engage school children in an authentic situation of socio-cognitive conflict and, acting within child's Zone of Proximal Development, support them in improving their wayfinding skills. In the present study it is included a digital representation of the humanoid robot because only few studies have investigated the differences in using physical robots versus virtual representations of the same robots in a tablet application. Li [23] presented a survey of 33 experimental works that comparing how people interacted with physical robots and virtual agents. The analyses verified that robots were more persuasive and perceived more positively when physically present in a user′s environment than when digitally-displayed on a screen either as a video feed of the same robot or as a virtual character analog. Westlund's recent study also gives similar results [24]. Westlund and colleagues have investigated differences in learning comparing the use of a social robot, a tablet and people, involving nineteen children, ages 4-6. Nonetheless the authors focused on a specific task (i,e., learning new words), results are really interesting. From the outcomes it emerges that all three interlocutors served equally well as providers of new words. However, children strongly prefer learning with the robot, and considered it to be more like a person. Nevertheless, it is possible that tablet is more effective in supporting the acquisition of some skills such as wayfinding ability.

3 Wayfinding and spatial orientation in children

Wayfinding, a specific spatial orientation ability, is a skill which consists in defining and following the path between an origin and a destination [25]. According to Piccardi [26] this ability is fundamental that has an evolutionary and ecological meaning for all organisms that are able to move. Piaget and Inhelder's studies [4] support the idea by which children gradually create a flexible geometric system that helps them to represent their spatial knowledge. According to the authors these mental schemas are constructed through active interaction with the environment and are related to the different phases of growth. Later, other researchers [27, 28] questioned the assumption that these knowledge systems are created from scratch. According to Spencer and Darvizeh [27] and Heft and Wohlwill [28] such schemas do not appear in specific stages of development but are always available to the child. Indeed, investigation shown that the advantage adults have over children in verbal interference tasks disappears in simple wayfinding tasks [29]. Behind this point of view there is the theory by which children do not have an advantage because of their new mental schemas but is because the adults, through the use of language, are able to benefit from different processing systems and different spatial information. Other studies showed that two-year-old children are able to use landmarks and geometric information in order to locate objects that have been shown and then hidden. Furthermore, children under the age of three can link spatial information to the left-right concept in a non-verbal mode, thus underlining the precociousness of spatial awareness [30]. Moreover, Cheng and Newcombe [31] verified that children between two and three years old who are spatially disoriented by a researcher, are able to orient themselves using exclusively environmental structures. Also, children between three- and four-years old use other types of information to find their orientation, such as the colours of objects [32], and children between five and six years old can use physical maps to move in experimental locations [33]. Liben and colleagues [34] wanted to evaluate the orientation abilities of children between nine and ten years old in a real space. Their results showed that children who achieved the best results in the spatial orientation test were also able, in the same way, to orient themselves more effectively in real spaces; they also found that males achieved better results than females in tests of spatial ability. Based on these assumptions, it is possible to say that the wayfinding ability is a competence that change over the time and a robotic partner could be able to improve it, especially in children. Benvenuti and Mazzoni [35] have discovered that robots are able to improve the wayfinding abilities of preschool children. Specifically, the study showed that children who performed the wayfinding task with a humanoid robot improved their performance significantly better compared with those who used a non-humanoid robot.

4 Objectives and Research question

Starting from social constructivism theory (human development is socially situated, and knowledge is built through interaction with others) [39], and from Papert's constructionism theory (knowledge and learning find expression in the realization and manipulation of concrete and material products) [38]; considering also the Vygotsky's concept of Zone of Proximal Development [1], it is possible to say that robots could improve children's abilities. In this regard, the aim of the present study is to investigate how 6-7 years old school children performed a wayfinding task supported by three different types of robot: i) a humanoid robot; ii) two types of non-humanoid robots; and iii) a digital representation of the humanoid robot made available in a tablets' robot-application. In particular, children were asked to instruct a robot to perform a given route, and the research wants to verify if robots, used like social partners or interactive tool, are able, acting within children's Zone of Proximal Development, to improve their wayfinding skills. Finally, this study wants to understand which types of technological artifacts can be more effective. Thus, considering all these goals the following hypotheses were formulated:

H1: The use of three different types of robot, humanoid robot, non-humanoid robot, and tablet, should significantly improve 6-7 years old children's wayfinding skills from pre-test to post-test.

H2: According to several study with children that shown that the use of a human-like robot behaving as a peer in the learning process can be highly effective [36; 13]: a humanoid physical robot should be more effective than a non-humanoid robot and the tablets' robot-application in a wayfinding task.

5 Methodology

5.1 Sample Description

The research test involved 227 6-7-year-old-school children (59,5% males and 40,5% females), randomly assigned to four different experimental groups and a control group (see Tab 1). The control group was composed of children who didn't perform any activity between the pre-test and the post-test.

Table 1. A sample of the study split by experimental conditions.

Robot used	Number of children
MecWilly	46
Blue Bot	59
Dash	59
Tablet	41
Control Group	22
Total	227

The study and related data processing were agreed with the schools and with the children's parents. The classes participated voluntarily in accordance with the teacher's joining up. The research was approved by the ethics committee of Bologna university.

5.2 Materials and Procedures

The present study used three robots, the humanoid robot MecWilly (https://mecwilly.it/), the non-humanoid robots Dash (https://www.makewonder.com/robots/dash/) and Blue Bot (https://www.tts-international.com/blue-bot-bluetooth-programmable-floor-robot/1015269.html), a tablet's robot application, and three chessboards on which robots move. These are different only for size: the smaller one is used for pre-test and post-test phase, the medium one for Blue Bot and the bigger one for Dash and MecWilly.
MecWilly is an interactive robot able to simulate human emotions and recognize human language, objects and environmental changes determined by human behavior.

Dash is a programmable robot equipped with wheels and distance sensors that allow it to move in all directions avoiding obstacles. The robot has four directional buttons and also it has three microphones.
Blue-Bot is a little robot designed to teach coding, develop problem-solving abilities and analyze action sequences. The robot has different directional buttons on its back (forwards, backwards, right and left), which allow the user to plan a route (each of Blue-Bot's movement covers 15 cm).
The tablet's robot-application is based on the MecWilly situation. Thus, the game show a chessboard on which an avatar of MecWilly has to be moved to achieve the objective: throw waste in the appropriate containers.
The research was carried out in the elementary schools which participated in the project. All the children were individually evaluated in a pre-test phase (before the experimental activity), in a test phase and in a post-test phase (after the experimental activity). The entire procedure took half a day per each class. The task was the same for the three experimental phases except for the robots that are used only in the test phase. During the task, a child sits alone opposite the experimenter, in the pre-test and post-test phase, and in front of the robot in the test phase, between them there is a chessboard (see Fig. 1).

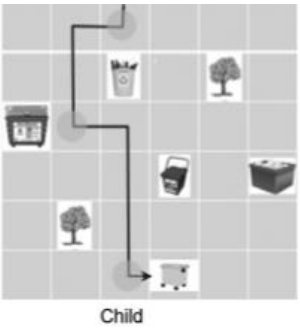

Fig. 1. The wayfinding tasks.

On the chessboard are placed, in specific squared, recycling bins: yellow for plastic, blue for paper, gray for non-recyclable waste, brown for organic waste and green for glass. In the proposed activity they represent obstacles that must be avoided by robots. During pre-test and post-test phase the children have to give experimenter the instructions to move a robot puppet around the chessboard, in order to arrive to the plastic bin. If the child gives instructions to move the puppet to an occupied space, the experimenter says that the puppet could not pass through the object, thus the puppet will stop in front of it. Data collected during the pretest and posttest phases were amount of time on task (in seconds) and number of moves required to complete the task, and these are the dependent variables that have been considered to assess the improvement on the children's wayfinding ability.
During the test phase, regardless the type of robot used, the children have to give the robot instructions (move forward, move backwards, turn right and turn left) to place a plastic bottle into the plastic bin. If the child directs the robot to a space occupied by a recycle bin, the experimenter says that the robot cannot pass through the object, thus

the robot will stop in front of it. The chessboard used for MecWilly and Dash is comprised 6 × 6 squares and measures 3 × 3 m instead the Blue Bot's one is 6 × 6 squares and measures 90 × 90 cm. The task could be accomplished in a minimum of nine moves over a maximum time of five minutes.
For the tablet's robot-application, the representation on the screen is the same of the MecWilly situation. However, the paths become more and more difficult the more problems the child solve within five minutes.

6 Results

This research was designed to analyze what improvements, if any, the children achieved in wayfinding when supported by two different types of robots, humanoid robot and non-humanoid robot, and by a tablet's robot-application.

Regarding hypothesis H1, a repeated measure T-test has been the used to determine if the use of four different types of tools, 1 humanoid robot, 2 non-humanoid robot, and a tablet, significantly improve 6-7 years old children's wayfinding skills from pre-test to post-test.). Table 2 shows the differences between the pre-test and the post-test, in all of four experimental conditions (MecWilly, Blue Bot, Dash, tablet's robot-application) and in the Control Group.

Table 2. Differences between pre-test and post-test about moves and time. $^{**}p < .01$, $^{*}p < .05$

Robot used	Pre-test moves	Post-test moves	Sign.	Pre-test time	Post-test time	Sign.
MecWilly	5,07	4,96	,490	142,20	84,83	,000**
Blue Bot	5,42	5,41	,932	159,22	100,41	,000**
Dash	5,51	5,31	,297	130,24	75,34	,000**
Tablet	9,27	8,37	,042*	76,00	44,22	,000**
Control	6,27	5,82	204	181,95	120,86	,000**

Results showed a significant improvement in the time required to perform the task in all of four experimental conditions (MecWilly, Blue Bot, Dash and Tablet's robot-application) but also, in the control group (probably due to an habitude to the task). However, the tablet condition shows also a significant difference between the number of moves required to perform the task, representing a clear improvement in the quality of the solutions found.
To evaluate if MecWilly (the humanoid-robot) is more effective in supporting children in wayfinding task than the other robots used in the present study (H2), a MANOVA was performed considering the difference between pre-test and post-test concerning the amount of time and the quantity of moves. Analysis showed a significant difference (,010) in time required to perform the task compared to the type of robot used (generally tablet seems to be more effective in improving time to perform the task), while no differences have been found concerning the quality of the performance. Thus MecWilly seems to be effective as much as the other robot and the tablet.

7 Discussion and Conclusion

The main objective of this study was to understand whether two different types of robots (humanoid robot and non-humanoid robot) and a tablet's robot-application, acting as social partner or interactive tool, are able to support 6-7 years old school children in acquirement of wayfinding skills. For this purpose, were collected the amount of time and the number of moves used by the children to solve the wayfinding task. The research is basically rooted in social constructivism theory (human development is socially situated, and knowledge is built through interaction with others) [39], in constructionism theory (knowledge and learning find expression in the realization and manipulation of concrete and material products) [38] and in the Vygotsky's concept of Zone of Proximal Development [39].

Hypothesis H1 was partially confirmed: only tablet's robot-application group did significant improvements in the amount of time and the number of moves required to perform the task. In all the other experimental groups, the robot did a significant improvement only on the amount of time. Also, in the control group is possible to see a significant improvement on the amount of time. This means that there is an improvement which is not determined by the experimental activities but is determined by doing the same task several times in a short time. The main implication of this results is that the tablet's robot-application is the only tool that effectively improve children's wayfinding ability.

Hypothesis H2 was not confirmed because, although there are differences in children's performance related to the types of robotic devices used, it is the tablet's robot-application that is statistically better than the other robots used in improving children's wayfinding ability but only in terms of time required to perform the task. No significant differences were found for the number of moves used. These results imply that the tablet's robot-application could be the best tool to support children in the acquiring of wayfinding ability.

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