Storytelling at School with a Robot Playmate

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Abstract— **The paper illustrates an exploratory case study on the use of a toy robot at school to support storytelling in children with cognitive disabilities. Play is a key factor in children's development, yet disabled children are often prevented from playing because of their physical or cognitive impairments. Robot toys might represent a suitable means of favouring learning through play in inclusive activities at school. The robot used in this study is designed to support play scenarios addressing different educational goals for children with specific needs. This paper describes a storytelling scenario and the experiment conducted with the robot in a primary school over four weeks. The activity involved a group of students with typical development and a child with a learning delay due to a mild cognitive disability. The results of the study show that the performance of the child with learning delay improved in terms of memorization of the story elements, ability to focus attention and reduction of exuberant motility when she played with the robot. The results are supported by qualitative and quantitative evidence, as well as by the comments of the teacher who participated in the study.**

Keywords-Children; Robot; Play; Learning; Disability; Storytelling; Primary school.

I. INTRODUCTION

Play has a crucial role in a child's development. The International Classification of Functioning and Disabilities, version for Children and Youth (ICF-CY) [1] published by the World Health Organisation defines play as one of the most important aspects of a child's life to be considered when assessing children's quality of life. Through play, children experiment and learn about themselves and the environment around them. In childhood, skills related to moving, exchanging, experimenting and learning mainly develop through play [2].

Several studies demonstrated that the absence of play is detrimental to the development of a healthy child, leading to impairment in their learning potential. This causes isolation and a compromises social life [3].

Disabled children are often prevented from playing due to their cognitive or physical impairment.

In recent years, an increasing number of research studies have revealed the benefit of using robots as a playmate to support the development of different skills in children with special needs. Robots support engaging and rich interactions while exhibiting a repetitive and controllable behaviour. This stimulates the child with a disability to try out the activity several times without feeling unable or impaired.

However, in order to effectively use the robot and achieve educational objectives, it is important to design play scenarios suitable for the child with special needs.

In what follows, we first provide a literature review on robot-assisted play based on storytelling activities, later we present the robot and the experiment conducted at a primary school with a child with mild cognitive impairment and her peers. The case study provides a detailed description on how to use the robot to engage children with different abilities in playful activities based on storytelling. Furthermore, it provides the results obtained in terms of learning and understanding of the dynamics of a story, and the social interactions enabled by the robot.

The paper is structured as follows. In Section II we report a literature review on storytelling robots; in Section III we present IROMEC (Interactive RObotic Social MEdiator as Companions), the robotic platform used in the present study, in Sections V and IV we illustrate the methodology and the experimental study carried out with IROMEC in a primary school with a child with mild cognitive disability and her classmates, in Sections VI and VII we report and discuss the results of the study. We conclude this work in Section VIII.

II. STORYTELLING ROBOTS

Developing a narrative competence is for children the privileged and primary way to begin to be part of the culture [4]. Narrative is also a fundamental aspect of meaning construction, which is a negotiation activity that develops from early childhood through the whole human life [4].

Narrative has three main functions [5]:
- Cognitive: as a way to learn.
- Social: stories allow us to identify ourselves with a social and cultural group.
- Emotional: as a therapy.

Storytelling is key of children's development. Through it children learn to express themselves and make sense of the external world. They develop logical thinking, imagination and creativity, but also social skills.

Remembering and understanding a story, or using a proper language are all competences that develop more slowly in children with a cognitive disability [6][7].

However, researches in schools revealed that if properly stimulated, children with a cognitive disability may improve in understanding and remembering a story, as well as in meaning construction and communication [6].

Recently, robots and virtual agents have been designed to promote interaction and communication through storytelling in children's development [8]. Lizeberg et al. [9] found that students have better learning performances if the interaction takes place with a physical agent rather than with a virtual agent.

A recent survey conducted by Chen et al. [8] classified storytelling robots in three categories based on who is the user of the robot, what is the focus of the study, and what is the outcome of the study:

- Users: children with typical development [10] and children with disabilities [11];
- Focus of the study: robots used in the educational context as learning companions, educational material, and teaching assistants;
- Outcome of the study: prototype, learning environment, authoring environment, and pedagogy experience.

In the context of disability, the robots are used with different goals. Plaisant et al. [11] used a storytelling robot to stimulate children in carrying out the rehabilitation therapy. Probo robot was used to provide assistance during the therapy with autistic children [12]. NAO robot was used as story reader with expressive verbal and nonverbal behaviours [13].

Storytelling robots are also used with children with normal development. Fridin [14] designed Kindergarten Social Assistive Robotics (KindSAR) a social assistive technology for kindergarten educational staff which provides assistance to the staff by engaging the children in educational games.

III. ROBOT PLATFORM

IROMEC is a robotic platform that addresses play as a medium for disabled children's learning, development and enjoyment [15].

The body displays graphic interface elements related to different play scenarios on a 13 inch digital touchscreen. For example, the body screen can represent the features of an imaginary cartoon-like character, displaying digital fur that moves according to the direction of the platform's movement. When the robot stops, fur clumps appear that extend when it moves again. The head consists of an 8 inch digital screen that displays the robot's facial expressions.

The platform is composed of passive and interactive hardware modules and configurable interfaces to enable the creation of play scenarios adapted to fit the needs of children with different kinds of disabilities [16]. Furthermore, the platform permits creation of new games that can be implemented through the "play script".

"Play scripts" allow implementation of Graphical User Interfaces (GUIs) for different play scenarios, so that the robot can turn from an imaginary animal covered with fur into a creeping snake, an agile tiger or a quiet turtle (Figure 1). The robot can show facial expressions incorporating the mouth, nose, eyes and eyebrows, as well as different levels of expressiveness and emotional states. Smooth transitions are used to create a life-like impression.

Figure 1. IROMEC imaginary animal-like character (left), IROMEC Tiger (centre), IROMEC Tortoise (right)

The interfaces are enriched by original sounds to structure and articulate the play experience. They have been designed in collaboration with experts, therapists and teachers to give the impression of a living entity without any specific human or animal connotations.

IV. CASE STUDY IN A PRIMARY SCHOOL

The study was conducted for about one month at "Giovanni Pascoli" elementary school in Siena, Italy.

The primary target of the study was an 8 year-old girl with a generalized cognitive delay associated with compromised ability to memorize, with limited verbal and communicative skills and motoric hyperactivity.

Her disorder was linked with difficulties in her life following removal from her family of origin at the age of 4. The early years of her life had been characterized by the presence of an environment providing little cognitive or affective stimulation.

The child's poor verbal skills had a negative impact on her ability to communicate and interact with the rest of the class. She was aware of this problem and felt frustrated by it. Her teacher considered integration into the class a priority goal.

The child had been included in the same curricular program as her classmates, with the addition of individualized activities with the support of a small group so that she would not be isolated.

In agreement with the special needs teacher, we decided to conduct the experimental sessions in a group, using the teaching model normally used in class, with three classmates involved in the study. The classmates' role was to facilitate the activity, promoting interaction, inclusion and the dynamics of play and learning.

The key goals of the study were:

- to improve the attention;
- to improve spontaneous verbalization and appropriate use of language;
- to improve narrative skills;
- to improve body awareness and coordination.

V. METHODOLOGY CASE STUDY IN A PRIMARY SCHOOL

The study was broken down into three sequential phases with the primary goal of ensuring understanding, learning and recall of the story *"The tortoise and the hare"* (Table 1).

TABLE I.   EXPERIMENTAL PROCEDURE

PHASE I	Reading the story "The tortoise and the hare" in the classroom			
PHASE II	**First sub session:** learning and recalling of the story through use of images	**Second sub session:** learning and recalling the story with use of the robot	**Third sub session:** learning and recalling the story with the use of the robot	**Forth sub session:** learning and recalling the story through use of images
PHASE III	Follow up assessment of the acquired knowledge (learning, understanding and recalling) through a questionnaire			

The maximum duration of Phase II was about 20 minutes, as suggested by the teacher in view of the girl's difficulty focusing her attention for a longer period of time. The sessions using IROMEC had an average duration of about 18 minutes, while the sessions in which images were used as an aid lasted no longer than 12 minutes. The length of individual sessions depended on the child's behaviour and response. If she appeared bored or refused to participate in the game, she was not forced to do so; the session was interrupted.

A. *Experimental phases*

Phase I: Reading the story "The tortoise and the hare" in class

The teacher brings up the story of "The tortoise and the hare" and reads it in class.

"Once upon a time there was a hare who, boasting how he could run faster than anyone else, was forever teasing tortoise for its slowness. Then one day, the irate tortoise answered back: "Who do you think you are? even you can be beaten!.. Beaten in a race? By whom? Not you, surely! I bet, there's nobody in the world that can win against me, I'm so speedy. Now, why don't you try?...." The hare is so confident that it will win that it takes a nap midway through the course. But when the hare awakes, he finds that his competitor, crawling slowly but steadily, has arrived before him."

After the reading, the children are asked to tell the story together. The teacher pays special attention to the little girl in question in order to assess her comprehension and her ability to recall the story.

Phase II: Learning the story with the reinforcement of images and with the IROMEC

The second phase was divided into four sub-sessions characterized by use of pictures (in the first and fourth sessions) and introduction of the IROMEC (in the second and third sessions), each focusing on comprehension, learning and recall of the story.

The sessions were conducted twice a week over a two-week time span.

- *First session: analysis, comprehension and recall of the story.*

Images were used to aid comprehension of the story in this activity. The teacher used the pictures to guide the session and analyse the key character: the tortoise.

At the beginning of the session the teacher asked the little girl a series of questions to judge her ability to recall the story read in class. If she had difficulty, her classmates were asked to help. Then the teacher asked a series of questions about the tortoise that helped the children recall specific elements: Where does it live? What does it eat? How does it move? When does it hibernate?. The girl could answer the questions while looking at the pictures (Figure 2).

Figure 2. Images used to guide the session

- *Second session: learning the story with the robot.*

The interfaces used during the activity transformed the robot in the "tortoise" of the story (see Figure 1).

In this specific configuration, the robot was intended to look and behave like a tortoise. The robot's mobile configuration was used so that it could move about the classroom alone or with remote control. The robot's movement simulated that of the tortoise, with rather slow movements in follow-me mode. This is a coordination game that consists of playing with the robot, which follows the child. The other children can compete to attract the attention of the robot in order to be followed. The primary educational objectives of this scenario are related to energy and drive functions and to improve motivation to act and to feel in control. The scenario aims to develop the understanding of cause and effect connections, and to improve attention to mobility.

The teacher asked the girl the same series of questions as in the previous session conducted with the use of images: Where does the tortoise live? What does it eat? How does it move? When does it hibernate?

In this session the teacher asked the girl and her classmates to answer the questions while paying attention to the robot's behaviour and imitating it. In this session the children acted out the story in a way, playing the roles of the two characters and mimicking their behaviour.

- *Third session: learning and recalling the story with the robot*

The third session was identical to the second.

- *Fourth session: recalling the story with the use of images*

The fourth session was identical to the first.

Phase III: Follow-up

Follow-up was performed a week later. Questionnaires were given to assess the skills (learning, comprehension and recall) acquired by the girl in relation to the story.

During follow-up the teacher asked the child to recall what had been done during the other sessions, both in sessions with images and in sessions with IROMEC, in order to assess how described below:

- *Cognitive area*

Attention: the child's ability to pay attention to visual and spatial stimuli connected with the play activity, expressed in terms of time. This indicator is continuous.

Recall of verbal and visual content: the child's ability to recall verbal and visual content previously presented and use it to help answer questions. Recall also refers to content presented in previous sessions. This indicator is intended to assess the child's ability to retain long-term memory. It is a spot indicator.

- *Motorial area*

Exuberant motility unrelated to the activity: excessive motorial activity of the entire body unrelated to the game being played. This is a continuous indicator.

- *Communication area*

Spot naming of an object or action: the child's ability to verbally identify an object or action using precise, appropriate language. The indicator refers to spontaneous mentions, not repetition or completion of words pronounced by the teacher or by classmates. This is a spot indicator.

Spontaneous verbalization: the child's ability to clearly and comprehensibly spontaneously verbalize statements on the activity underway. The indicator does not include cases in which the statement is solicited by the teacher's questions or cases in which the spontaneous verbalization is unrelated to the context of the activity underway. It is a continuous indicator.

A written questionnaire was given to the children during the follow-up phase, and included multiple choice questions about the story and the character of the tortoise.

VI. RESULTS

A.   Phase I: Reading the story "The tortoise and the hare" in class

Observation of Phase I in class session revealed that the child had difficulty paying attention to multiple stimuli, associated with difficulty in recalling concepts presented not long ago.

For example, when the teacher asked *"Do you know the story of the tortoise and the hare?",* the child answered *"No",* but at the end of the reading she picked up the book and said, *"I know this story, because I have the cartoon at home".* The girl spontaneously began telling the story in very simple words:

"In the cartoon, there's a tortoise and… the other one… I don't remember… what it's called… and then they have a race and … the other one… I can't remember what the other one's called....." and when the teacher prompted *"the hare",* she seemed not to hear her but continued her story: *"Yes there was a hare and it ran very fast".*

In response to the teacher's question, *"Who won the race, the hare or the tortoise?"* the child replied *"the hare"* without hesitation. Though the teacher pointed out that her answer was wrong, she continued to claim, *"In my cartoon it's the hare that wins".*

The teacher had to remind her to pay attention repeatedly while reading the story. The girl gave the impression she was "hearing" and "seeing" what was happening around her, but not intentionally "listening" and "watching". Her attention seemed to be attracted primarily by the pictures in the book shown by the teacher, not by the story. She could not answer the questions asked of her without the teacher's help and the images. For example, in response to the teacher's question *"Is the hare fast or slow?"* the child hesitated and the teacher had to show her a picture of the two animals to elicit an answer.

The vocabulary she used was simple and very limited. The answers she gave often repeated the teacher's words.

During the reading, the child sat in a listening position with her arms crossed and resting on her desk, but did not seem to be at ease, and repeatedly moved her legs. She often picked up objects on the table during the reading, distracting herself.

B.   Phase II: Learning the story "The tortoise and the hare" with the aid of images and with the IROMEC

The information obtained from video analysis of the sessions with the aid of images and with the IROMEC reveal the child's growing ability to pay attention visually (cognitive dimension) to the visual and spatial stimuli connected with the activity.

Visual attention was constant and prolonged in the sessions with the IROMEC, lasting almost the entire session, 18 minutes and 90 seconds out of 19 minutes and 10 seconds in the first session with the IROMEC and 18 minutes out of 18 minutes and 20 seconds in the second session. In both sessions, the child was only distracted from the activity underway for about 20 seconds during the first phase. In the sessions involving use of images, the duration of her visual attention in relation to the total duration of the session was significantly lower. The child was distracted from the game for extended periods of time, 3 minutes and 44 seconds in the first session and 4 minutes and 73 seconds in the last session. As noted above, the sessions involving use of images did not last as long as those involving use of the IROMEC, for the duration of the sessions was strictly dependent on the child's behaviour. The total duration of sessions involving use of images was 11 minutes and 20 seconds for the first session and 13 minutes and 40 seconds for the second. The Figure 3 shows the value in relation to total time, expressed in minutes and seconds, of the child's ability to pay visual attention to the visual and spatial stimuli presented.

These results are correlated with the results of exuberant movement indicator (motorial dimension), which tends to decrease during sessions conducted with the IROMEC and increase in sessions using images.

During sessions conducted with images, this indicator has a value of 3 minutes and 2 seconds, as compared to a total of 11 minutes and 20 seconds in the first session, and

7 minutes compared to a total of 13 minutes and 40 seconds in the second session. In sessions conducted with the IROMEC, her motorial activity was reduced to 0.67 minutes out of a total of 19 minutes and 10 seconds in the first session and 0.38 minutes out of a total duration of 18 minutes and 20 seconds in the second session.
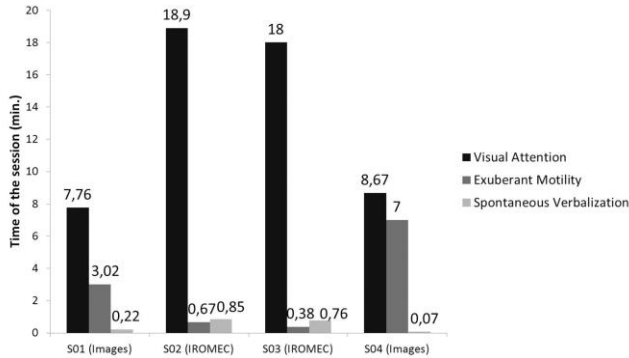

Figure 3. Results of: visual attention, exuberant motility and spontaneous verbalization

Her exuberant motility, which the teacher repeatedly had to contain in order to continue with the activity, translated into inappropriate behaviour, such as pretending to fall, rolling around, repeatedly tying her shoes or leaving the scene of the activity (Figure 4).

Figure 4. Session with the use of image

Spontaneous verbalization, as opposed to statements solicited by the teacher's questions but pertinent to the activity underway, did not exceed one minute in any of the sessions, as shown on the graph in Figure 3.

Spontaneous verbalization was lower in sessions involving use of images, in which the child participated verbally only when asked to do so by the teacher. In these sessions she made statements primarily linked with personal events and aspects unrelated to the activity underway, which distracted her from what was at hand. This form of communication is typical of her pathology and her experience, as noted by the teacher, who explained that the child used this technique in class to avoid tasks which were difficult for her to perform.

In the sessions involving use of the IROMEC, spontaneous verbalization was higher, though only by a few seconds; the child used precise terminology consistent with the context, interacted more frequently with the group

and participated in the discussion, asking questions about the IROMEC and pertinent to the activity underway.

Her ability to recall verbal and visual content presented previously (cognitive dimension) improved significantly, from 12 items of content recalled after the first session with images to 21 items of content recalled in the first session with the IROMEC a figure which remained constant in the last session.

In sessions involving use of the IROMEC, the child demonstrated a greater ability to use different verbal content from that pronounced previously; she was, for instance, capable of using synonyms. This did not occur in the sessions conducted with images, where the teacher had to repeatedly prompt verbal content to complete an enunciation.

In the area of communication, the figures reveal that the child acquired a growing ability to name objects and actions narrated in the story with precision (Figure 5).
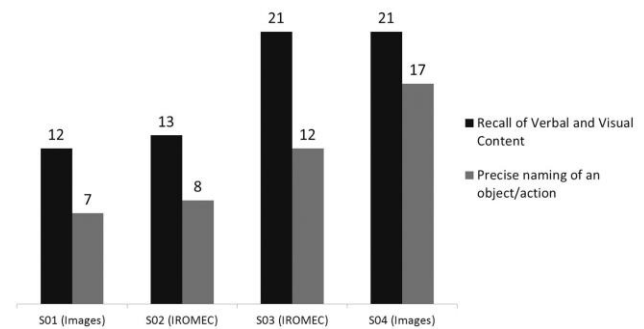

Figure 5. Results of: recall of verbal and visual content, precise naming of an object/action.

The figure reveals a progressive increase from 7 items of content named with precision in the first session to 17 items of content in the last session.

C. Phase III: Follow-up

A week after the end of the sessions, the child was asked to answer two different sets of questions, about the story and the characteristics of the tortoise.

The questionnaires were constructed according to instructions provided by the teacher, who regularly uses this type of test to assess acquisition of knowledge, normally after two lessons on a specific topic. As the teacher pointed out, in this kind of tests the child under observation almost always demonstrated difficulty filling in the questionnaire independently and needed help choosing the right answer.

In this study, the girl was able to fill in the questionnaires alone and answer the questions correctly without any help.

After the questionnaires had been filled in the teacher asked the children some questions about what they had done. The discussion revealed that the child had less difficulty recalling the content of sessions conducted with the IROMEC than sessions conducted with images. The girl specifically recalled activities involving motorial activities, such as imitating the slow movement of the robot representing the tortoise, and particularly the feedback on

whether or not an activity had been performed correctly. This was made explicit in the child's words.

Teacher: *Now can you tell me what you liked most about all these things we did with the pictures and the little robot?*

Girl: *That the tortoise laughed that I was slow.*

VII. DISCUSSION

The data obtained from video analysis reveal that the sessions conducted with the IROMEC favoured the child's ability to pay attention and her learning and memorization of the story, decreasing the amount of behaviour inappropriate to the activity.

The results were discussed with the teacher, who expressed considerable satisfaction, particularly with the child's ability to remember the content between the two sessions conducted with the robot, as compared to the sessions with images. The teacher emphasised that involvement of the motorial sphere in addition to the cognitive sphere made a significant contribution to learning and memorization of the story.

The results of the study reveal that the child's ability to concentrate changed depending on the type of aid used (images/IROMEC). In sessions conducted with the IROMEC she was able to focus her attention constantly for a long time, focusing on the robot and on the feedback the IROMEC sent, while in the sessions with images her attention was attracted to her surroundings rather than focused on the activity underway.

An interesting aspect which emerged in sessions with the IROMEC as compared to sessions with images was the climate in the group, which was inclusive and social, revealing greater interest in the story.

VIII. CONCLUSIONS

The paper reports the outcomes of an exploratory study on the use of a toy robot at school to support storytelling in a girl with a mild cognitive disability. Results show that the robot promoted active participation and involvement on the part of the girl, reducing the inappropriate behaviour and exuberant motility which was normally present when doing schoolwork. Active involvement of the motorial sphere in the learning process facilitated learning of abstract concepts which are difficult to understand. The possibility of mimicking the behaviour of the characters of the story like the slowness of the tortoise and the speed of the hare with her body allowed the child to understand concepts which would otherwise have been difficult for her to learn.

IROMEC's presence promoted spontaneous verbalization and communication among the disabled child, the teacher and the other children. The child repeatedly asked the teacher questions about the robot's behaviour, such as *"What is it doing? Why is it turning around?"* referring to the robot turning around to face the children.

This interaction with the teacher had not occurred in the sessions conducted with images, where, to the contrary, there was practically no communication unless solicited by the teacher's questions.

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