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“Robot, tell me a tale!”: A Social Robot as tool for Teachers in Kindergarten

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Abstract

Robots are versatile devices that are promising tools for supporting teaching and learning in the classroom or at home. In fact, robots can be engaging and motivating, especially for young children. This paper presents an experimental study with 81 kindergarten children on memorizations of two tales narrated by a humanoid robot. Variables of the study are the content of the tales (knowledge or emotional) and the different social behaviour of the narrators: static human, static robot, expressive human, and expressive robot. Results suggest a positive effect of the expressive behaviour in robot storytelling, whose effectiveness is comparable to a human with the same behaviour and better when compared with a static inexpressive human. Higher efficacy is achieved by the robot in the tale with knowledge content, while the limited capability to express emotions made the robot less effective in the tale with emotional content.

Keywords: Educational robotics; Human-Robot Interaction; Kindergarten; Social Robotics; Storytelling.

1. Introduction

In natural communication, human beings use social behaviours, like gestures, eye gaze, and tone of voice, to supplement speech and to augment the language, thus providing a composite multimodal perception to other humans that can use multiple cues for better understanding.

The Social Agency Theory posits that when an artificial agent uses a multimodal interaction, this is perceived as more similar to the human-human interaction and its persuasive power increases (Ham, Cuijpers, & Cabibihan, 2015; Mayer, Sobko, & Mautone, 2003). Based on this principle, a novel class of robots that exhibit social behaviour is being developed (Fong, Nourbakhsh, & Dautenhahn, 2003; Goodrich & Schultz, 2007; J. Li, 2015), thus, opening up numerous possibilities for further innovation in children's education (Ioannou, Andreou, & Christofi, 2015; Jacq, Garcia, Dillenbourg, & Paiva, 2016; Kennedy, Baxter, Senft, & Belpaeme, 2016), including those with learning difficulties and/or intellectual disabilities (Conti, Di Nuovo, Buono, & Di Nuovo, 2017; Dautenhahn & Werry, 2004; Robins et al., 2012; Robins, Dautenhahn, & Dubowski, 2006). In this context, robots can mix the flexibility of a virtual agent with the advantage of being embedded into a physical environment where information can also be sensed by vision, hearing, and tactile perception (Hsu, Chou, Chen, & Chan, 2007). In fact, robots can be "engaging, motivating, encouraging imagination and innovation, and may improve literacy and creativity, especially for children" (Chen & Wang, 2011). Educational robotic assistants are expected to facilitate children's learning and they may improve their literacy and creativity (Serholt et al., 2016), for example an educational robot-based learning system can improve motivation and interest in learning

(Chin, Hong, & Chen, 2014). However, this does not necessarily mean that robots are more effective than humans or other devices in teaching, but only that they can be powerful tools in the teacher's hands.

This article presents a study that examines the effects on pre-school children of learning from a robot with and without social behaviours. To this end, we investigated the use of the social humanoid robot Nao as a storyteller by analysing the memorization of two tales by 81 kindergarten children. We programmed the Nao robot to tell two different tales, one with emotional content "The Ugly Duckling" and one with knowledge content "The Emperor's New Clothes". Then, in the classroom, we experimented using two conditions for the robot, static and expressive, by asking the children to draw pictures of the tales. In the analysis the pictures were evaluated by comparing them to those drawn by the children after they had been read to by a human teacher with similar social behaviours.

2. Related work and hypotheses

2.1 Robots in education

Robotic tools are well-known to enhance the acquisition of Science, Technology, Engineering, and Mathematics (STEM)-based competencies (De Cristoforis et al., 2013) and other types of competencies such as collaboration, imagination, and self-expression (Alimisis, 2013). Robots are currently being used in a variety of topics to teach young children, from mathematics and computer programming to social skills and languages (Lopez-Caudana, Ponce, Cervera, Iza, & Mazon, 2017; Mubin, Stevens, Shahid, Mahmud, & Dong, 2013; Toh, Causo, Tzuo, Chen, & Yeo, 2016). For a systematic review of research trends see (Jung & Won, 2018). This has gained popularity especially thanks to low-cost and highly-accessible educational robotic kits (Sklar, Parsons, & Stone, 2004). Physical devices make the learning explicit and concrete, and increase students' motivation because they can build and program their own robots and participate in competitions (Williams, 2003). In practice, educational robots can be categorized into three types (Chang, Lee, Wang, & Chen, 2010; L.-Y. Li, Chang, & Chen, 2009): learning materials, learning companions, and teaching assistants/tutors. Robots are an especially useful tool when applying problem-based learning (Arlegui, Pina, & Moro, 2013), project-based learning (George & Leroux, 2001) or challenge-based learning approaches (Jou, Hung, & Lai, 2010). Moreover, it has been shown that robots can increase students' motivation towards a subject (Rees, García-Peñalvo, Jormanainen, Tuul, & Reimann, 2016).

2.2 Social Robotics for children's education

A social robot can be defined as "an autonomous or semiautonomous robot that interacts and communicates with humans by following the behavioural norms expected by the people with whom the robot is intended to interact" (Bartneck & Forlizzi, 2004). As a virtual agent with a physical body, a social robot can play the role of a human through speech and sound, gestures, and other sensorial expressions (Druin, 1999; Feil-Seifer & Matarić, 2011). This class of robotic platform usually resembles the human body, and they are therefore known as "humanoid robots" or, simply, "humanoids".

In the context of children's education, social robots can increase the attention level and engagement of young children (Lopez-Caudana et al., 2017), who can achieve better learning outcomes when they are highly engaged (Ponitz, McClelland, Matthews, & Morrison, 2009). Studies have focused on humanoid robots and show that young children can more easily socialize with humanoids and that the relationship can persist for lengthy periods (Kanda, Sato, Saiwaki, & Ishiguro, 2007; Tanaka, Cicourel, & Movellan, 2007). Recently, Tanaka and Matsuzoe (2012) found that learning can be enhanced by encouraging children to talk to the robot, thus teaching or educating the robot.

2.2.1 Storytelling with robots

For younger children, storytelling is a powerful way to educate by conveying knowledge and culture, communicating ideas and feelings and by supporting language learning and development. In this context, a robot may be seen as an extension of old storytelling methods which used puppetry, traditional theatre, dolls, or pets. Previous research into human-robot interaction explored the use of robots as storytellers (Chen & Wang, 2011), showing how, over other technological devices, social robots have the advantage of enriching the narration by expressing simulated emotions, which can be articulated with posture and gestures by the humanoid robot that resemble human behaviour (Pelachaud, Gelin, Martin, & Le, 2010). In a previous study (Fridin, 2014), storytelling was used with 10 children as a paradigm of a constructive educational activity and teaching of new concepts and motor skills. The experiment was designed to examine how a robot in the kindergarten can be used to engage preschool children in constructive learning. Results show that the children enjoyed interacting with the robot and accepted its authority (Fridin, 2014). In storytelling, robots were integrated with other media, e.g. PowerPoint presentations, and increased children’s embodied participation and engagement (Sugimoto, 2011). A robot's gazing and gestures can improve its persuasiveness (Ham et al., 2015), and this proved to help increasing infants’ vocabulary (Movellan, Eckhardt, Virnes, & Rodriguez, 2009), promoting language expressiveness during storytelling (Gelin, d'Alessandro, et al., 2010).

2.2.2 Effect of robot's gestures and other social cues

Robot tutors that can make gestures may be particularly effective because children can benefit from gestures more than adults (Hostetter, 2011), and, moreover, gestures increase children's attention to the learning materials (Valenzeno, Alibali, & Klatzky, 2003). For instance, pointing gestures by a robot can significantly improve the comprehension of spatial information presented by a human experimenter (Cabibihan, So, Nazar, & Ge, 2009). In another study, it was found that gestures that are linked to speech affect message evaluation and judgment about the speaker more positively than gestures not linked to speech or no gestures at all (Maricchiolo, Gnisci, Bonaiuto, & Ficca, 2009).

Other studies of social cues underline the role of gazing in human-human communication. An individual's gaze is commonly used to establish whom the person is talking and listening to (Vertegaal, Slagter, Van der Veer, & Nijholt, 2001). Head movement and gazing have been found to play an important role in compliance with unambiguous requests in human-human interaction (Kleinke, 1977). Mutlu, Forlizzi, and Hodgins (2006) observed that a robot's gaze direction has the effect of information retention in storytelling. In fact, their experiment with few participants shows that the ones who were gazed at more by the robot remembered more of the story than those who were gazed at less. They also found a different attitude between men and women: men liked the robot more when it gazed at them more, while women liked the robot more when it looked at them less.

Social agency theory also suggests that the accent and tone of voice can facilitate the understanding of conversational agents (Atkinson, Mayer, & Merrill, 2005; Louwerse, Graesser, Lu, & Mitchell, 2005; Mayer et al., 2003). Specifically, the results of two experiments conducted by Atkinson et al. (2005) are consistent with social agency theory which posits that social cues in multimedia messages, including the type of voice, can influence how hard students try to understand the speaker and the presented material. Moreover, in two off-line experiments, the authors found that participants preferred natural agents with natural voices (Louwerse et al., 2005), as predicted by the social-cue hypothesis.

Recent research shows that the combination of multiple social cues can lead to a more persuasive robot (Ham et al., 2015). The study considered a robot gazing and gesturing when telling a story to adults, and results showed that persuasiveness increases when both social cues are present; when robots didn't use gazing, the use of gestures decreased their persuasiveness. Finally, Pelachaud et al. (2010) showed that students had significantly better recall of story details when their teacher made eye contact with them while reading.

2.3 Hypotheses

In the light of the previous robotics research and the social agency theory, we hypothesize that a robot storyteller would be more effective when it uses social cues to augment the narration. At the same time, we hypothesize that our expressive robot will be as effective as the human teacher by mimicking human social behaviour.

To this end, we tested the following hypotheses (H1–H2) for two tales with a different type of content (emotional and knowledge):

H1. Children will report more elements and details of the narrated tale with a robot showing human-like expressive behaviour.

H2. Children will report a similar level of elements and details with a robot and human with the same social behaviour.

The number of a tale's elements and details recalled by children after the storytelling can be measured from children's drawings. This technique is often used in studies with preschool children (e.g. Bhamjee, 2012), because drawing is a regular activity in kindergarten and an effective method for children to report their understanding of tales, whereas they could have difficulties in expressing themselves with only words (Rennie & Jarvis, 1995). Therefore, we requested the children to draw what they recalled of the tale with coloured pencils, then we analysed the drawings to find elements and details of the tale with the procedure described in Section 3.6.

3. Method

3.1 Participants

We selected four kindergarten classes, balanced for age and gender, from a school in the province of Catania, Italy. Our experimental sessions attracted over 100 children, who agreed to participate in at least one session. Of these, only 81 children (n=81, Males=45, Females=36, *M*-age=5 years, range= 5-6, *SD*=0.33) attended all sessions and were included in our analysis. The children had never seen a physical robot before the study.

We chose participants of 5-6 years because they are in the preoperational stage and this is the age at which children develop intuitive thought, characterized by realism, animism, and artificialism (Piaget, 1951). In this phase, the child creates mental schemes in order to mentally represent objects and events, with the development of fiction, language, and drawing. Indeed, at this stage of cognitive development, when drawing, the child does not copy reality as it is, but represents it, reporting only what for him/her has more importance and meaning.

Considering what has been said above, we used a between-subjects experimental design which required a similar number of children in both conditions and for this reason groups were randomly assigned to either a human or a humanoid robot storyteller. Then, each group was further split per storyteller behaviour: expressive condition, or static inexpressive condition. In accordance with University ethics procedures for research with children, parents provided written consent prior to their children's participation. Children also provided verbal assent prior to taking part in the tasks, and tasks could be discontinued at any time at no disadvantage to the children. All the data was securely stored and was not presented in any way that might disclose individual identities or performances. Furthermore, the kindergarten teachers actively participated in the design of the procedure and approved the final implementation.

3.2 Experimental Design & Material

Our research methodology followed the one used with a human storyteller by (Mutlu et al., 2006), whereas we investigated whether a robot storyteller could be more persuasive if it used gazing, gestures and voice modulation in a human-like manner.

After consultation with teachers, we selected two completely new stories for children, i.e. which had never been told before either at school or at home. Also, the wording of the tales was carefully reviewed using feedback from teachers in order to ensure that the vocabulary and difficulty levels of the stories were appropriate for the age, thus, that the children would be fully able to comprehend.

The tales selected for the experiment were: “The Ugly Duckling” and “The Emperor’s New Clothes”, both by Hans Christian Andersen. The latter tale was formed by words and has knowledge content (i.e. it taught the children new concepts), while the main content of the former tale is emotional. In particular, in the cognitive content the second story argues the importance of truth knowledge, where the awareness and understanding of facts, truth or information is obtained through experience or learning. While the emotional content of The Ugly Duckling focuses primarily on affective relationships, familiarity, contact, and on emotional “feeling”.

To prevent loss of children's levels of attention because of the length of the tale or unknown words, with the help of the teachers, we reviewed the tales in such a way that the narrated versions contained about 900 words known by all of them. In fact, originally the two tales had a different number of words, 1744 vs 3964 respectively. Considering this difference, with the help of the teachers, we reviewed the text to reduce the length and include only those words that were already “assimilated” by the children. However, in order to these prevent tales from losing their true meaning, based on the classical studies by Propp (2010), we defined a structural level for each tale that contained a title, an exposition, potentially followed by a scene, including a triggering event, from which the tale unfolds.

To build these lexicons, we relied on the notion of gesture variant and gesture family introduced by Calbris (1990). A gesture family encompasses several instances of behaviours, which may differ in shape, but convey similar meanings. Thus, the entries in the lexicons of the robot and of the agent are part of the same gesture family, even if they differ in shape (Gelin, D'Alessandro, et al., 2010).

In a pre-study, before the experimental session with the groups, one of the teachers confirmed that the lexicon was suitable by telling the tales to 4 children (n=4, Males=2, Females=2, *M*-age=5 years) who did not take part in the experiment.

Distribution of children among the modalities is shown in Table 1. In Table 1 and the following tables, for compactness, the groups are labelled as follows: EH identifies the group with an Expressive Human storyteller (N = 21); SH identifies the group with a Static Human storyteller (N = 19); ER identifies the group with an Expressive Robot storyteller (N = 21); SR identifies the group with a Static Robot storyteller (N = 20).

Table 1. Participants' distribution.

Storytelling	Human storyteller	Robot storyteller
Expressive modality	EH = 21	ER = 21
Static modality	SH = 19	SR = 20

3.3 The Nao Humanoid Robotic Platform

The robot used was the Softbank Robotics *Nao*, which is a small toy-like humanoid robot, very popular for child-robot interaction studies (Coninx et al., 2016; Conti, Di Nuovo, & Di Nuovo, 2019; Conti, Trubia, Buono, Di Nuovo, & Di Nuovo, 2018; Fridin, 2014). Nao is 58 cm high, weights 4.3 kg and can produce very expressive gestures with 25 Degrees of Freedom (DoF) (4 joints for each arm; 2 for each hand; 5 for each leg; 2 for the head and one to control the hips). Nao can detect faces and mimic eye contact moving the head accordingly, it can also vary the colour of LEDs in its eyes contours to simulate emotions, and it can capture a lot of information about the environment using sensors and microphones. Nao is programmed with a graphical programming tool, named *Choregraphe* (Pot, Monceaux, Gelin, & Maisonnier, 2009), which provides an intuitive way to design complex behaviours, including several interfaces for non-verbal communication, i.e. including gestures, sounds, and LEDs.

Nao was programmed to perform actions and movements, while telling the stories using the embedded text-to-speech functionality. To improve the children's understanding of the Nao robot, we set the volume at 90/100 and slowed down the language speed to 80/100. We chose this in agreement with the teachers and the research aim, considering the voice, volume and speed of language of the human narrator. The voice we used was the standard Italian provided by the robot manufacturer.

Therefore, the robot was programmed to exhibit two conditions: The first was the baseline condition that only has the tale being told by the robot in a "static" modality, i.e. gazing absent (white colour led), hands, legs and trunk gestures were absent, and monotonous voice characterized by a tone that did not change according to the tale's words. There were no gestures, so the robot sat, motionless, with no changes in gaze colour which remained white for the duration of the tales.

The second condition had an "expressive" robot that made gestures, gazing and modulating its voice like a human storyteller. In the expressive mode, Nao was standing up while expressing appropriate emotions both with the body (moving arms and head, changing eyes' LED colours) and vocally (adding sounds according to the contexts). In the static mode, Nao was sitting on the table without moving. An example of the robot's expressive storytelling is shown in Figure 1.

Figure 1. Robot expressive storytelling.

Specifically, the expressive condition was characterized by gestures of the hands, legs and trunk to accompany and mimic the objects and the adventures told in the tale. For example, in the knowledge tale Nao robot clapped his hands while saying “Oh! How beautiful are our Emperor’s new clothes! What a magnificent train there is to the mantle; and how gracefully the scarf hangs!”, and in the emotional tale case Nao robot bent its head down after saying at a lower pitch “Kill me! Said the poor creature”. Moreover, the robot’s eyes changed colour (green, red, blue or white) according to specific situations, e.g. red for danger, at the same time the voice modulated the pitch, the volume and the emphasis on the words spoken, e.g. a louder voice and higher pitch when introducing the Emperor.

3.4 Classroom setting

The children were arranged in a semi-circle (see as example Figure 1) on chairs that allowed them to see the robot or the narrator properly. Two cameras were installed in the room where the children usually carried out their activities, to record all the phases of the study. The robot was placed on a table in the centre of the room. The distance between the robot or the human narrator and the children was about 80 centimetres. We chose this distance, known as "Personal distance" (Hall, 1974) because physical distance at this level usually occurs between people who are family members or close friends. The closer a person can comfortably stand while interacting can be an indicator of the intimacy of the relationship.

3.5 Experimental procedure

The procedure was performed during regular kindergarten hours. The time slot chosen was between 10 and 12 am, a period typically used in the kindergarten for drawing activities.

The storytelling session procedure was simple and similar for both narrators. In the expressive modality, the human was following a script in order to make the storytelling as similar as possible to the robot program. The narrator initiated the storytelling session by greeting the children and explaining the current activity to them. After narrating the tale, to conclude each session, the Nao robot thanked the children for participation and communicated that it must go to recharge its batteries. This final part of the interaction with the robot was intended to emphasize a robot's limitation to comply, as far as possible, with the ethical requirement of avoiding the children becoming emotionally attached to the robot and suffering from the subsequent separation (Tanaka & Matsuzoe, 2012).

The experimental procedure included 3 encounters, each of around 15 minutes, distributed over 3 weeks:

1) To decrease the novelty effect, there was a preliminary session in which the robot was first introduced to all the children involved. After a self-presentation, the robot performed a dance (*Gangam*-style), then it walked and autonomously interacted with the children using the built-in autonomous life modality. This introductory session lasted about 15 minutes and

was presented to all classes in the school, separately, regardless of whether they were involved in the study or not.

2) In the second week, children were divided into four groups according to the narrator (human or robot) and the modality (expressive or static). Then, the robot or the human narrated the emotional tales.

3) Finally, in the third week, the knowledge tale was told by Nao robot or human, expressive or not, to the same groups from the previous week.

The teachers were present during all three sessions described above. They represented a “secure base” in a new situation (Bowlby, 2005), where they could support children in case of any needs or requests.

After the storytelling, the robot or the human storyteller asked the children to use coloured pencils on a white A4 sheet, to draw all the details they were able to recall about the narrated tale, without time limits. Given the age of the child and to avoid an excessively structured “climate”, we used these drawings to gather concrete quantitative data of what children memorized of the tale. Examples of children's drawings are in Figure 2.

(a)

(b)

Figure 2. Examples of children's drawings: (a) A drawing of "The Emperor's New Clothes" tale; (b) A drawing of "The Ugly Duckling" tale.

In conclusion, after the drawings had been returned to the teacher, in adherence with the ethical principle of equality among groups, we presented the expressive version of Nao to all children involved who hadn't experienced this modality (groups: SR, EH, SH).

3.6 Data Analysis

Two researchers independently coded the drawings from the sessions. Both coders first coded the drawings from the excluded participants to become familiar with the coding scheme. Once the agreement between coders was reached, coding began on the remaining data. Coding was completed for the 162 collected drawings (81 participants for 2 sessions). For each drawing, we determined how many main elements and additional details of the stories were represented by the children. The main elements were plot, character, settings, and themes, while additional details included actions, objects, and descriptors that were part of the tale. We eliminated the additional details, intrusions or distortions that are produced by the children, e.g. opinions, feelings or thoughts. Parts identified as elements were not counted in the details and vice-versa. Fewer elements than details were expected to be reported by the children. Figure 3 shows an example of the coding.

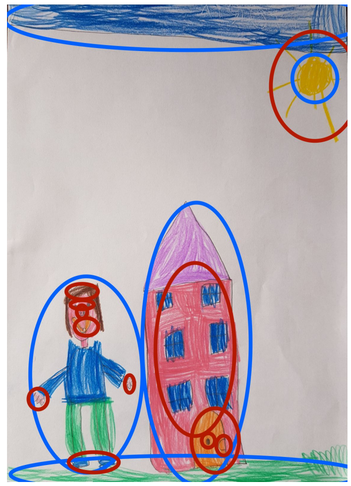

Figure 3. Example the coding of drawings. Elements are circled in blue and details in red. In this case, we counted 5 elements (person, castle, sun, sky, grass) and 11 details (rays, hands, feet, mouth, nose, eyes, hairs, windows, door, handles, viewing hole).

Experimental results have been analysed by group. To evaluate the results, we first performed an exploratory one-way MANOVA with the Tukey HSD post hoc test for multiple comparisons among the mean differences of all groups and modality-measures pairs. Then, we calculated the effect size as the mean difference of each pair of conditions and calculated the Cohen's *d* to evaluate the magnitude of the effect. *d* is a descriptive measure defined by Cohen (1988) as the difference between the means (μ) divided by standard deviation (σ). Cohen (1988) argued that the pooled standard deviation (σ_{pooled}) should be used when the variances of the two groups are not homogeneous:

$$Cohen's\ d = \frac{\mu_1 - \mu_2}{\sigma_{pooled}} = \frac{\mu_1 - \mu_2}{\sqrt{\frac{(\sigma_1^2 + \sigma_2^2)}{2}}}$$

The Statistical Package for Social Sciences (SPSS) version 24 was used for statistical analyses.

4. Results

We can report that all the experiments went smoothly, as planned, and none of the children showed any problem with the robot. From the observation of videos of the sessions, we noted that the children were strongly attracted by the social robot and demonstrated higher attention and compliance with the procedure than with the human storyteller. This has been confirmed by the teachers attending the sessions. Meanwhile, some children gave signs of being bored by the static robot, for instance, during storytelling, they asked the teachers "when is the robot going to finish?" or "when does the robot dance again?'".

Table 2 presents the descriptive statistics of the analysis of the drawings: for each content type and group, it reports the mean and standard deviation of number of elements and of details recalled by the children after the storytelling.

Table 2. Results of the analysis of the drawings, Mean and Standard Deviation (*SD*).

Content Type	GROUP	SH		SR		EH		ER	
	Measure	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Emotional	Elements	2.79	1.18	2.15	1.04	4.14	1.90	3.10	1.70
	Details	3.37	1.42	3.65	1.98	8.52	3.46	6.57	5.35
Knowledge	Elements	2.68	1.45	2.60	1.47	3.10	1.34	2.90	1.51
	Details	4.63	2.71	5.40	1.60	7.57	2.44	8.24	4.29

According to the MANOVA, there was a statistically significant difference in performance among the groups, $F(12, 196.08) = 13.74$, $p < .001$; Wilk's Lambda = 0.588, partial $\eta^2 = .16$.

Table 3 presents the difference of means for details and elements for each storyteller/behaviour pair. Table 3 is split into 4 parts according to content type and group. Differences with statistical significance $p<0.05$ are in bold. We see that there is no significant difference between human and robot with the same social modality, while expressive storytelling generally helps the children to recall more details regardless of the storyteller (human or robot). In terms of elements, the only significant differences are for the emotional tale with the human storyteller.

Table 3. Multiple comparisons of mean differences: mean of groups in rows minus mean of groups in columns

	Emotional Tale					Knowledge Tale				
Elements	**E1**	**SH**	**SR**	**EH**	**ER**	**E2**	**SH**	**SR**	**EH**	**ER**
	SH	-	*0.64*	***-1.35****	*-0.31*	**SH**	-	*0.08*	*-0.41*	*-0.22*
	SR	*-0.64*	-	***-1.99****	*-0.95*	**SR**	*-0.08*	-	*-0.50*	*-0.30*
	EH	***1.35****	***1.99****	-	*1.04*	**EH**	*0.41*	*0.50*	-	*0.19*
	ER	*0.31*	*0.95*	*-1.04*	-	**ER**	*0.22*	*0.30*	*-0.19*	-

Details	**D1**	**SH**	**SR**	**EH**	**ER**	**D2**	**SH**	**SR**	**EH**	**ER**
	SH	-	*-0.28*	***-5.16****	***-3.20****	**SH**	-	*-0.77*	***-2.94****	***-3.61****
	SR	*0.28*	-	***-4.87****	***-2.92****	**SR**	*0.77*	-	*-2.17*	***-2.84****
	EH	***5.16****	***4.87****	-	*1.95*	**EH**	***2.94****	*2.17*	-	*-0.67*
	ER	***3.20****	***2.92****	*-1.95*	-	**ER**	***3.61****	***2.84****	*0.67*	-

* statistical different ($p<0.05$) differences are in bold.

Finally, Table 4 presents the pairwise Cohen's *d* measures for details and elements calculated for each content type. The *d* measures above the medium magnitude are in bold. The *d* measures confirm that magnitudes of the effect size are small or negligible in the cases of human and robot with the same social modality, while there are larger effect sizes for the details when the expressive robot is compared to the static robot and human.

Table 4. Cohen's *d* of pairwise comparisons. Magnitudes above medium (0.5) are in bold.

Content Type	Measure	Pairs					
		SR-SH	ER-SH	EH-SR	ER-SR	EH-SH	EH-ER
Emotional	Elements	-0.41	0.15	**0.92**	0.47	**0.60**	0.41
	Details	0.12	**0.58**	**1.22**	**0.51**	**1.38**	0.31
Knowledge	Elements	-0.04	0.11	0.25	0.14	0.21	0.09
	Details	0.24	**0.71**	**0.74**	**0.62**	**0.81**	-0.14

5. Discussion

With regard to our first hypothesis (H1), results in Table 3 show that the expressive social behaviour of the robot increases the number of details reported by the children with a median increase of 3 items drawn for both stories. Meanwhile, the social behaviour of the robot doesn't seem to have a significant effect on the memorization of main elements, which is similar among modalities and tales. However, there is no significant difference in elements recalled between expressive and static human, suggesting that social modality has a limited influence on the memorisation of the main elements of a tale with knowledge content. It should be noted that tales have multiple details per elements, with the latter often being repeated several times during the storytelling. Indeed, details can be considered as stronger evidence of performance improvement, because being able to recall more details is usually associated with better development of cognitive skills (Laak, De Goede, Aleva, & Rijswijk, 2005).

Regarding H2, we found no statistically significant differences between human and robot storytellers with the same social behaviour. However, the expressive robot facilitates the children in memorizing more details than the static inexpressive human storyteller.

In the comparison between the robot and the human storytellers, we noted differences between the two tales; in fact it was only in the case of the emotional tale’s elements that the expressive robot didn't significantly outperform the static human. In fact it performs slightly worse than the expressive human in both elements and details, even if not statistically significant. We could conclude that a social robot can be a powerful tool in the hands of teachers, who can use this novel technology in the role of an assistant to engage the children and can off-load some tasks to the robot. In fact, if robots are not disrupting the learning, teachers can use the capability of robots for other concurrent tasks such as monitoring the class.

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6. Conclusions

In this paper, we investigated the use of a social humanoid robot as a storyteller for kindergarten children. To this end, 81 children were recruited from the same kindergarten school and were exposed to either a human or a robotic narrator in different conditions: static, i.e. without social behaviour, or expressive, when the narrator used meaningful gestures, eye gaze, and voice tone to accompany the speech.

Analysis of the experimental results shows that pre-school children can memorize more details of a tale if the robot narrates with an expressive social behaviour. The positive effect has been discovered for two types of tales, with emotional and knowledge content, and for both human and humanoid robot storytellers.

In comparison with the control groups, the humanoid robot performed as well as the human with the same social modality. Results show a comparable number of main elements and details reported by the children in all conditions tested with no statistically significant pairwise difference between the two narrators. Furthermore, the expressive modality of the social robot made children able to recall more details of stories than an inexpressive human storyteller. It must be noted that the humanoid robot used for the experiments performs better in the story with knowledge content, while it seems slightly less effective in the case of the emotional tale, which, we hypothesise is because it can't exhibit facial expressions.

We could conclude that a social robot can be a powerful tool in the hands of teachers, who can use this novel technology in the role of an assistant to engage the children and can off-load some tasks to the robot. In fact, if robots are not disrupting the learning, teachers can use the capability of robots for other concurrent tasks such as monitoring the class.

Indeed, the long-term goal of this research is to develop a multitasking robotic system that can be used at the same time for supporting teaching and learning, and for the assessment of developmental disabilities and personalised intervention though child-robot interaction. Examples and discussions of robot-assisted diagnosis for children can be found in (Petric, Miklic, & Kovacic, 2017; Scassellati, 2007; Scassellati, Admoni, & Matarić, 2012; Wijayasinghe, Ranatunga, Balakrishnan, Bugnariu, & Popa, 2016).

Finally, we remark that robotic tools should never replace a human teacher who can better identify and meet children's needs and requests and prepare them for social life. Therefore, the human must always be in control of the class and be the leader of the learning activities while taking advantage of technological aids.

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This article extends a previous abstract (Conti, Di Nuovo, Cirasa, & Di Nuovo, 2017) by introducing an extensive literature review, presenting more details on the experimental procedure and giving a deeper analysis and discussion of the results.

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