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Robots and children learning differently: A brief review of robot applications for young children

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Abstract

With technological advancements, children today may learn in ways that can be radically different from how their parents did. Considering the learning differences, the purpose of this review is to explore robot use for its potential benefits in educating today's children who need to be learning differently from the generation before. As children are growing up in an increasingly tech-savvy world, this review would serve to raise the awareness of robot applications developed for young children, so that more people can be sensitized to the adoption of robots for early childhood education. The studies and reports included in this review are a selection of robot applications used with children in the general population of early childhood (0 - 8) years. Based on collaborative efforts in function and design such as the use of puppetry, as well as curriculum design in areas such as behaviour modification, social or motor skills, numeracy, language and literacy through storytelling and/or games, the robot applications reviewed here have been found to present with great potential for a dynamic way to educate the young. Implications for use with children with special needs are discussed.

Keywords: Robot applications, young children, learning differently, general population.

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INTRODUCTION

Many children today will likely grow up into a world that is radically different from what their parents know and may be in professions that have not even been heard of yet. The idea that traditional professions can be potentially transformed due to the use of robots has lately been highlighted for many people. It is truly amazing how the roles of robots have evolved from traditionally carrying out mundane heavy duty or hazardous work in factories such as those in the automobile industry, to interactive service roles such as those in the education, hospitality and service sectors and even in the home of the man on the street. Driving such changes could be the shift in consumer preferences in an increasingly digital world. According to a recent Forrester Report (see Vitec Inc., 2016), only 28 percent of U.S. online consumers "prefer to contact companies via telephone or e-mail rather than using a company's website to get answers to their questions". As younger generations form the greater part of this market segment, they are likely to drive up the proportion of people who would prefer not to interact with humans for support (Vitec Inc., 2016), but to deal with a computer.

Due to the similarities between the two, virtual agents may be perceived by many as robots; hence, it is necessary to start with a technical distinction between them. According to Looije, van der Zalm, Beun, and Neerincx, (2012), a virtual agent is not a robot but an animated virtual character (usually with anthropomorphic appearance) with artificial intelligence that is generated by a computer. The authors pointed out that embodiment is the key difference between a virtual agent and a robot. The similarity, on the other hand, as pointed out by Vitec Inc. (2016) is that both are embedded in a program with predefined scripts and responses. They can be powered by a knowledge base, which contains a wide-ranging list of possible different questions, answers and gestures, allowing them to respond to human input in a somewhat human way.

Reportedly (see Coninx et al., 2016), robots not only have the core advantage over virtual agents in terms of real world interaction and manipulation (Stiehl et al., 2009; Shibata, 2011), but the physical robot is also more appealing to user perceptions (Komatsu & Abe, 2008; Wainer, Feil-Seifer, Shell, & Mataric, 2007). There is also the unconscious effect of the presence of a physical robot, as studies such as the one by Looije, van der Zalm, Beun, and Neerincx (2012) showed that the frequency and length of gaze of fifth grade children is greater for a real robot than a virtual form of the same robot. Coninx et al., (2016) also reported that when using real robots, the benefit to performance or other outcome is shown in ta number of contexts: learning (Bartneck, 2003; D. Leyzberg, Spaulding, Toneva, & Scassellati, 2012), motor skills (Kose-Bagci, Ferrari, Dautenhahn, Syrdal, & Nehaniv, 2009), and long-term behaviour change (Kidd & Breazeal, 2008).

With the advantage of embodiment over virtual agents to suit the context, the use of robots with young children is explored here for its potential benefits in educating today's children who need to be learning differently from the generation before. As children are growing up in an increasingly tech-savvy world, this review would serve to raise the awareness of robot applications developed for young children, so that more people can be sensitized to the possibilities of adoption of robots for early childhood education. The review of studies and reports here is a selection of those applications used for children in the general population of the early childhood (0 - 8) years. The features of the review besides this brief introduction to robots are the type of robot used in the study and the context of use. The review concludes with a discussion on the implications and limitations found in the studies, as well as the implications for us with children with special needs. A quick overview of the robots discussed here and the research on which the findings are based is tabulated in Appendix 1.

LITERATURE REVIEW

Robots as programmable toys

Children learn through play, especially in preschool. Starting with simple robots that young children are familiar with, such as a toy car robot which can be programmed to move in various directions, forwards or backwards, left or right, etc., children can be taught the skills and language of giving directions to a robot. Problem-based learning (PBL) can be woven into the task. This involves problem-solving using executive function skills in planning the steps to take, such as getting to a specific location on a map. Language, literacy, numeracy or other subjects to be taught can be incorporated into the PBL curriculum.

To illustrate, an objective of a lesson may be to program the robot to travel to a spot on a map that has a corresponding alphabet for a letter sound, or a number that is the symbol for a given quantity. The children would therefore need to first find the answer to the question and then identify the number parameters on the map that has it. Then, they can be taught the skills in programming the robot to travel a number of squares in a prescribed direction on the map to the correct location. These ideas are not entirely new, and date back to the seminal work of Seymour Papert, who devised the Turtle, a small robot directed by young children using a simple computer language Logo in the 1970's (Stager, 2016). Clearly, the technical specifications of the current robots have benefitted from an explosion in the capabilities for interaction and application.

Robots such as the Bee-Bots and Pro-bots (from TTS Group Ltd, UK), the KIBO (from KinderLab Robotics, USA) and the KIWI robotics kits (from Tufts University, USA) are examples of programmable robots used in studies on preschool-aged children. In a study by Highfield (2010), Bee-Bots and Pro-bots were used as a catalyst for mathematical problem solving in an Australian classroom. Eleven of the children were aged 3 and 4 years and they were from a metropolitan pre-school. The brightly coloured Bee-Bot on wheels is apparently appealing to little hands and the plastic covering works well for easy cleaning in child care hygiene.

More recently here in Singapore, Play@TP, an experimental kindergarten in Temasek Polytechnic used the KIBO robotics kit as a tool for 35 of its preschoolers to acquire specific learning goals such as using programming skills to solve problems, as well as to tinker with technology (see Ng, 2015). Initially, the children made Chinese New Year cards with LED stickers and copper strips, and connected electrical circuits to power light bulbs and mini fans, to familiarize themselves with the potential of technology in play. In the study, the children created a sequence of instructions by scanning the wooden KIBO blocks to tell the robot what to do as it travels on its wheels, using buttons or an iPad program. This pilot study found that the children's concentration and perseverance in the face of difficult tasks improved with the use of this tool, and their co-operation in problem solving increased. For the KIWI robotics kit, a study on preschool children in the USA was done by Sullivan and Bers, (2016). The robot was also used like a vehicle as it has wheels. The children in the study successfully programmed their robots to go from point A to point B using number parameters on a map. The novelty of some programmable robots such as these is that they can do even fancier moves like dancing, spinning or producing flashing lights, sounds and music.

Learning how to pre-programme a robot to perform tasks autonomously has its advantages overusing a remote control to manipulate a robot's actions and movements which is more commonly known. Although a robot response can be elicited more spontaneously with a joy stick or a button control, this may result in unwanted human error or impulsive moves. Such issues can be avoided with careful pre-planning of an autonomous sequence of actions in relation to the environment. While the joystick cannot be shared and children may squabble over who gets the control, programming provides the platform for them to make shared decisions and for the work to be divided into different focal areas to start with, thus curriculum time can be better optimized. Besides, teaching such programming language uses the executive function skills of problem-solving in sequencing, estimating and planning which have been identified as a key factor in successful early learning.

Programming toy robots can thus be a novel way of helping children understand the elementary workings of industrial robots such as the autonomous forklift used in the logistics sector, and other autonomous or self-driving vehicles adapted for use on land, and even air and sea as well. Consequently, children are given early exposure to STEM (Science, Technology, Engineering and Mathematics) education through the use of such robots in their curriculum. This would make them potentially more able to contribute to the development of robotic solutions to overcome constraints in resources in our world.
Robots as teachers

The drive for the research and development of robots has resulted in increasingly more complex robots being developed, so robots do not just perform laborious physical tasks but can become socially interactive as well. Such robots may take on human-like forms, so that young children are less likely to be afraid to interact with them. Robots that take on human-like forms are known as humanoid robots. The use of remote control with robots can be very helpful when the robot is used to take the role of a teacher. In this role, the robot can be much bigger than a toy bee or car; hence the risk of damage caused by child mishandling is reduced. The other plus factor is that the control of the robot is in the hands of the human teacher instead of the student.

With remote control, humanoid robots can be used as a tele-presence tool to deliver lessons from a remote location, thus becoming like an avatar for the teacher. These robots have more complex abilities than the toy robots designed to be manipulated by children. To alleviate the workload of teachers, additional robot functions have been developed for robots to present learning materials, and even carry out administrative, entertainment, and/or social roles. The EngKey English teacher 'robot' from the Korean Institute of Science and Technology (KIST), South Korea is one such an example. This robot functions as a tele-presence tool that brings English teachers located in the Philippines to the schools in South Korea (see Grzybowski, 2013). Besides its popularity with the children, EngKey has also helped to address the shortage of qualified native-English speaking teachers in South Korea.

Humanoid social robots

Humanoid Social Robots (HSRs) have also been developed to function autonomously. One of the earliest autonomous HSRs used experimentally with children in early childhood is Infanoid (from the National Institute of Information and Communications Technology, Japan), which had worked with a sample of children averaging 5 years old (see Kozima , Nakagawa, and Yano, 2005). This robot is an upper-torso humanoid robot as big as a 3- to 4-year-old human child. Each of its two hands has four fingers and a thumb, just like a real child, for a variety of functions such as pointing, grasping, and other hand gestures. It is also capable of producing various facial expressions, like surprise and anger with its lips and eyebrows. Hence, Kozima et al (2005) pointed out that with Infanoid, children could progress from perceiving the robot as just a mindless moving thing, to realizing that it can operate not only as an autonomous system, but as one that initiates motion based on the attention and emotion it possesses.

Following Infanoid, Robovie (see Kanda, Nishio, Ishiguro, and Hagita, 2009), another HSR, capable of human-like expressions was also used experimentally with a large sample of young children (this time aged 6-7 years old; including 59 boys and 60 girls). Robovie (from ATR Intelligent Robotics and Communication Laboratories, Japan) is an upgrade from Infanoid as it has a much larger repertoire of expressions, consisting of 100 different behaviours (70 interactive, 20 idling and 10 moving) to engage children in daily communications. On top of this, Robovie also has the additional function of recognizing individuals using ID equipment. Reportedly, the children enjoyed interacting with the robot, and some even expressed sympathy for it. Kanda et al., (2009) highlighted that it was one of the first studies that provided evidence of children rapidly adapting to an interactive humanoid robot and developing relationships with it. The humanoid robot has also been improved to look more life-like, such as the Hanson Robokind Zeno R50 (from University of Sheffield, UK). Compared to Infanoid and Robovie, Hanson which has a realistic silicon rubber ("flubber") face that can be reconfigured is not only more life-like as a peer, but is also more toy-like as a smaller HSR that can be placed on a table. Children were engaged in collaborative play in the game of "Simon Says" and facilitating helping behaviors towards robots in the experiments with this robot (see Cameron, Collins, et al., 2015; Cameron, Fernando, et al., 2015).

Another small HSR that functions more like a peer is NAO (from Aldebaran Robotics, France). It has also been used experimentally with young children, playing various roles in projects around the world. In one study under the ALIZ-E project, NAO was used for engaging children in a quiz game, an imitation game and a dance game. This robot was able to initiate, participate, and collaborate in the interactions (see Belpaeme et al., 2012). In another study under the ALIZ-E project, NAO's role was to act as a peer for a diabetes-related education through play programme in a hospital environment (see Coninx et al., 2016). Apart from the ALIZE-E projects, NAO was also used in the L2TOR project as an early childhood second language tutor (see Belpaeme et al., 2015). Nao is so versatile that it was even used as a dance robot tutor in the context of creative dance as well (see Ros & Demiris, 2013).

Nao has also been used as a teacher-assistant in other studies under the KindSAR project (see Fridin, 2014), where it performed tasks such as assisting teachers by engaging children in educational games and by telling pre-recorded stories to small groups of children while incorporating song and motor activities in the process. In another KindSAR project as a teacher-assistant, Nao was used to collect data on children's development over time with respect to their performance of specific tasks and responses to specific situations (see Keren and Fridin, 2014). More recently, Nao has even been put to work with another larger humanoid robot called Pepper (from Aldebaran Softbank Robotics, France). Pepper, with an embodiment like C-3PO from the Star Wars movies, was used with NAO for experimentation on collaborative play and interactive storytelling in a preschool project in Singapore (Info-communications Media Development Authority, 2017).

Using the learning-by-teaching paradigm, Nao has also played the role of a facilitator to encourage collaboration among young children. Harkening back to the days of Infanoid, only the upper-torso of NAO was used in this study, as it provided more stability for NAO to be placed on a table top in an attempt to showcase the versatility of its use (see Chandra et al., 2015). Young children with handwriting difficulties had also benefitted from the use of NAO as a learner in "Learning by Teaching a Robot: The Case of Handwriting". This study was also based on the learning-by-teaching pedagogy, for the learning of the psycho-motor skill of handwriting (see Lemaignan et al., 2016).

Autonomous social robots as child-minders

Autonomous social robots have also been featured in reports for their role in child-minding and preventing child-care accidents. One such model is the hybrid humanoid H3 robot from Advanced Industrial Science and Technology, Japan (see Simo, Nishida, and Nagashima, 2006). This robot is a hybrid because the robot's autonomous control can be superseded remotely with a combined fish eye camera and the parent's voice (via robot speakers) - used on the basis that it would be more familiar and appeal to the child better. In this way, it can be tweaked to overcome the limitation of the child ignoring the robot's articulated words during the experimentation of interactive storytelling.

For the very young, a small (11 inches tall) yellow snowman-shaped tabletop robot called Keepon (pronounced, "key-pong") has been experimented with 0-year-olds (from 6 months of age), 1-year-olds, and over-2-year-olds. Keepon (from the National Institute of Information and Communications Technology, Japan) is designed to perform emotional and attentional exchanges with children especially, in the simplest and most comprehensive way (see Kozima, & Nakagawa, 2007).

PaPeRo - "Partner-type-Personal-Robot" from NEC Corporation, Japan, is another model of small HSRs (see Osada, Ohnaka, & Sato, 2006). With an embodiment like R2-D2 from the Star Wars movies, PaPeRo has popularly been used in children's groups at day-care centers/homes, kindergartens and elementary schools. This robot is purported to be capable of recognizing and verbally communicating with people, sending images by mobile phone, as well as playing games and singing along with others.

Sized a little larger than PaPeRo is iRobi from Yujin Robots, South Korea. With telepresence functions, iRobi is commonly used as a teacher's aide there (see Palk, 2010). Originally designed as an educational toy, iRobi has an expressive digital face and an interactive LCD screen on its torso. It can be programmed to perform dances, tell stories, take digital photos, and maintain a virtual organizer. According to the CNN report by Palk, 2010, iRobi and a robot dog named Genibo have been helping out pre-school teachers in the city of Daejeon, and South Korea had aimed to introduce eight hundred and thirty of these types of robots into pre-schools by the end of 2010, with the goal of having them in kindergartens nationwide by 2013.

Creature-like robots

Robots that are creature-like, such as Sony's three models of 4-legged robotic dogs known as AIBO, were studied before, with young children by Stanford University, USA (see Okita & Schwartz, 2006). The sample consisted of thirty-two children from a university day care program with an age range of 35-66 months. The Sony AIBO robotic dogs from Japan, which came before South Korea's Genibo, were used in the study which focussed on young children's understanding of animacy and entertainment robots.

Other than taking on the embodiment of a dog, there is a robot with the embodiment of a cat. This should come with no surprise as such animal embodiments would make robots appealing to children as common domestic pets. Genibo was originally invented to play the role of a pet robot, but was redesigned to teach dance moves and gymnastics instead. The cat robot study used a robot known as iCat (from University of Birmingham, UK), which is a social robot that plays the role of a game companion for children using an electronic chessboard (see Castellano et al., 2013). Twenty-six Portuguese elementary school children (8 - 10 years old) took part in the study. It was found that iCat's empathic behavior, generated as a response to the user's emotions, positively affected how the children perceived the robot. They not only perceived the robot as a more engaging and helpful companion, but also provided higher ratings in terms of self-validation.

Other creature-like robots developed and experimented with children had plush features. These include the Show & Tell Robotic Puppets for preschool education (from NTU, Singapore) (see Causo et al., 2015), the DragonBot (from MIT Media Lab, USA) - an 18" dragon-like squash-and-stretch robot covered with a plush skin designed in collaboration with an expert puppeteer (see Kory & Breazeal, 2014) and the Tega robot (also from MIT Media Lab, USA) - a personal robot for social purposes (see Westlund et al., 2016). Both Tega and DragonBot (designed as a social character that interacts with children as a peer rather than a tutor or teacher) take those creature-like robots used experimentally with children to a higher level because of their interactive social features. Tega actually worked collaboratively with a virtual agent in the study, and accompanied the child participant on a pretend trip to Spainto learn new words in Spanish together. The DragonBot on the other hand, was programmed to play a storytelling game, introduce new vocabulary words during the game, and model good story narration skills. Data was also recorded to find out if the children learnt the target words from the experiment, and whether their language ability had improved overall after playing with the robot. The children’s language was also transcribed and analyzed for content and structure. This included measures such as the number of words spoken and the language complexity.

DISCUSSION AND CONCLUSION

In this review, there are robot applications for the following uses: a) to teach children how to program a robot to execute physical movements and/or producing light and sound effects (e.g. KIBO and BeeBots); b) to administer a service (e.g. physical/social companionship, entertainment, teaching and/or child-minding). For the latter, the robots can be pre-programmed to autonomously respond to stimuli in both the physical and social environments. Such robots may be fitted functional hardware such as a camera for emotional recognition, playback for text to speech, motors for motion execution and microphones for speech recognition for its interactive functions. Although the repertoire of such robots can be limited, the development of hybrids with remote control to override the programmed functions is one way to overcome certain limitations.

Yet, hybrids may not be a fail-safe option as the social context for interaction can be unpredictable; hence, their adaptation to the child's needs can still be inadequate. For instance; a child-minding robot may still fall short of recognition and active responding in situations where it's job it so prevent imminent accidents (Osada, 2006). Therefore, even with remote control over-riding options, collaborative human efforts are still needed to ensure that children can remain engaged with the use of the robot so that the objective(s) set can be met.

With the advantage of embodiment over virtual agents, robots can be human-like or creature-like in form, and be constructed with hard coverings, human-like skin or animal fur -like covering. Hence, as with product design, the form, size and material used are factors to be considered for practicality of use in terms of durability, hygiene maintenance, context and appeal. For instance, the Bee-bot with its bright yellow hard covering is attractive and easy to clean. In addition, it is small enough for young children to manipulate it like pressing the buttons with their little fingers. With respect to the appearance of the robot, there is considerable potential to work in collaboration with experts. For example, the DragonBot was designed in collaboration with an expert puppeteer.

Generally, the robots reviewed here have proven to be popular with the children. An expert at KIST reported that "Children feel the robot is their friend. Robots are very helpful to enhance the concentration capability of children in class" (see Palk, 2010). As for teachers' feedback, some of the key takeaways are from those found in the TEGA robot study (see Figure 1 below - Westlund et al., 2016): "Consider how the study activity can complement curricular goals; teacher experience with the robot matters; be prepared early; identify and involve stakeholders from the beginning; make time to pre-pilot with stakeholders; involve teachers while respecting constraints on their time and attention; teachers are the experts in their classrooms; minimize disruptions; one-on-one and small group robot interactions can add value to the classroom; share with the whole class; promote curiosity."

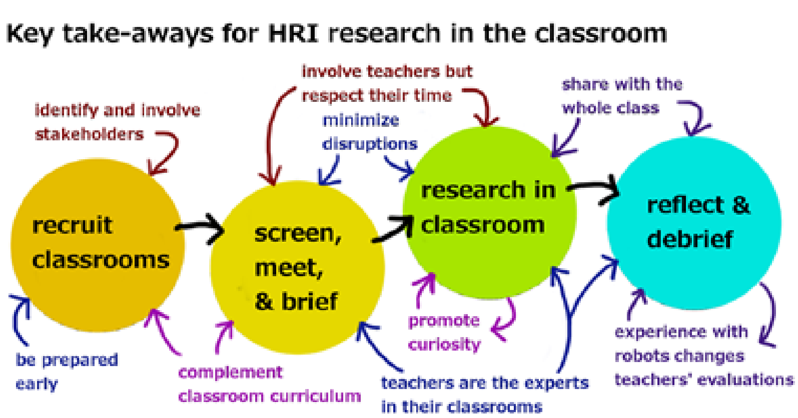

Figure 1 - Lessons we learned during research in preschool classrooms, and where this advice applies to the research cycle (Westlund et al., 2016)

In choosing an appropriate robot application for teaching, other than considering an appropriate robot size and appearance to appeal to children or prevent misuse, the functionality of the robot needs to be aligned to one's objectives in using the robot. A robot's functional abilities may be limited in toy robots such as the KIBO or Bee-bot as they are not social robots and the repetitive nature of the activity can cause the novelty of the robot to wear off. Mishandling of small robots by children is a factor to consider as the damage can be costly and lessons may need to be cancelled or modified in replacement.

In comparison, social robots are more versatile than toy robots that are just for children to tinker with programming, as social robots have a repertoire of social interactive behaviours. Besides considering the social repertoires, another factor to consider is the size appropriateness for children's use, especially the very young. For example, in the study *Personalizing robot tutors to individuals' learning differences*, Keepon, the small tabletop robot, was chosen because of its size and the fact that it was particularly well suited to expressive non-threatening social communication (Leyzberg, 2014). To illustrate the latter - if the puzzle-solving strategy lesson in the experiment needed to be repeated, Keepon would start by apologizing for repeating itself by saying, "I'm sorry to repeat this hint but I think this will help." (Leyzberg, 2014, p3).

In designing the curriculum for subject areas such as behaviour modification, social or motor skills, numeracy, language and literacy through storytelling and/or games, there is the potential for collaboration with parties (storytellers, game designers, dance choreographers, etc.) who have the relevant expertise as well. With the structured, consistent and non-threatening or non-judgmental style of robot behavior, special-needs children, such as those with dyslexia or autism, would stand to benefit as well from a customised curriculum developed in collaboration with specialists. Hands-on activities such as programming a toy robot to travel to find an answer, dancing, playing games, quizzes with a robot or teaching a robot how to write would very likely pique their interest in learning! What's more, robots such as Nao can collect developmental data on changes over time, the DragonBot can analyse speech and language to investigate spoken communication. The future potential in reinforcing learning in an effective and appealing fashion could well be limitless.

Almost a decade ago, it was reported that technology curricula were unavailable and specific technological tools for special needs education was scarce in Finland (see Virnes, 2008). This was even as special needs education recipients made up almost a third of the school children between the ages of 7 and 16. The researcher implored: "The increasing number of special-needs children and the need for early intervention challenge teachers and researchers in this field to discover new and more effective solutions to the problems of special-needs children. Robotics, in the form of programmable construction kits and social robots, could make as great a contribution to improving the quality of special needs education. Technologies of this kind could enable educators to recognize children's individual needs at an early stage of education and to compensate for their diagnosed disabilities. Robotics could also empower special-needs children to experience success in the learning of those technical skills that are central to our technology-oriented society" (Virnes, 2008, p30).

There appears to be much interest in the use of robots for educating children by authorities around the world now. Under the Infocomm Media 2025 Plan in Singapore, technology-enabled toys have been introduced progressively to 160 pre-school centres to foster creativity and problem-solving skills among children, through its Playmaker programme (see Info-communications Media Development Authority , 2017). Back in 2010, CNN had reported that the South Korean government was pressing ahead with plans to expand its "R-learning," (robot learning) program. Should we fear that governments would attempt to substitute real teachers with robots? The report mentioned that the South Korean government has no such intentions but plans to develop robots that provide assistance to teachers that meet expectations. Besides, the experts mentioned in the report expressed doubts that a robot will ever be better than a person. The reason given was that teaching is probably the most challenging role for artificial intelligence as it is a creative role and to teach well, one really has to understand the person being taught. Therefore, it was reported that a real fundamental leap in ability would be required before robots are capable of leading a classroom on their own.

To conclude, the studies reviewed here show that all over the world, there is a myriad of uses for robots for children in the early childhood years. As with other disruptive technologies, the adoption of robot applications may be challenging, but users' feedback would be helpful to help researchers improve the functionality of robots in by meeting the objectives set for children's learning. Therefore, the contribution from existing studies and the on-going pursuit of knowledge in child–robot interaction (CRI) is expected to continue to drive research and development of robots for children to greater heights.

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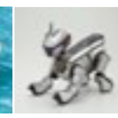
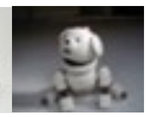
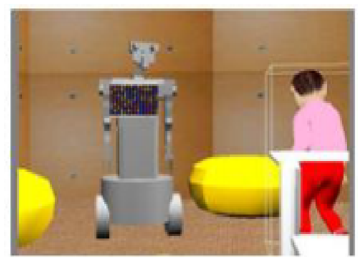
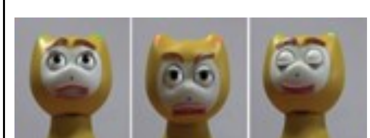
APPENDIX 1: ROBOTS

FUNCTIONS	FINDINGS	AGE GROUP
1. AIBO ERS-210, ERS-220A, ERS-311A‡).		
3 behaviors the dogs could complete; Kick, Dance, Stand Still. Used on young children's understanding of animacy and entertainment robots.	The results showed that the children would not confer animistic properties evenly. Also, the children attributed intelligent behavior more than biology and agency.	32 children from a university day care program. Range 35-66 months   
2. BEE-BOT AND PRO-BOT		
Used to perform 3 different types of tasks: structured tasks (teacher-directed tasks designed to develop particular concept or skills); exploratory tasks (structured to allow application of knowledge, exploring concepts and skills more freely); and extended tasks (open ended and child-directed tasks with which children engaged for an extended period of time, and with limited teacher scaffolding.	A combination of structured and exploratory tasks allowed students to develop and apply skills in programming and controlling the robotic toys. Extended tasks provided opportunities for students to attend to multiple mathematical focuses simultaneously.	33 children, of whom 11 were aged 3 and 4 years from a metropolitan pre-school. 22 Year 1 children from a nearby state school. 
3. DRAGONBOT		
The robot It is designed as a social character that interacts with children as a peer, not as a tutor or teacher. It will play a storytelling game, during which it will introduce new vocabulary words, and model good story narration skills, such as including a beginning, middle, and end; varying sentence structure; and keeping cohesion across the story.	Children learn more from a robot that adapts to maintain an equal or greater ability than the children, and they will copy its stories and narration style more than they would with a robot that does not adapt (a robot of lesser ability).	20 children ages 4-6.  Figure 1: Two social, interactive robotic characters, called dragonbots, used as language learning companions for young children.

FUNCTIONS	FINDINGS	AGE GROUP
	4. ENGKEY	
A tele-presence tool that brings English teachers located in the Philippines to the schools in South Korea. The instructors in the Philippines communicate using embedded microphones and speakers.	The robot controlled by teachers abroad was used to communicate using embedded microphones and speakers. The EngKey's small display with a woman's face mimics the facial expression of the teacher, who has cameras in his/her room.	A pilot pre-school class. 
	5. GENIBO QD - AN AUTONOMOUS PET ROBOT	
The Genibo QD can identify itself and the surroundings using its sensors, camera, and voice commands and share feelings with the user. With input information, it forms Emotion/Mood/Intelligence/ Character/Intimacy' to feature unique character and AI.	Nil.	A pilot pre-school class. 
	6. HANSON ROBOKIND ZENO R50	
Used for collaborative play - Simon Says. Hanson Robokind Zeno R50 has a realistic silicon rubber ("flubber") face, that can be reconfigured, by multiple concealed motors, to display a range of reasonably life-like facial expressions in real-time.	The results provide new evidence that life-like facial expressions in humanoid robots can impact on children's experience and enjoyment of HRI. The presence of expressions could be seen to cause differences in approach behaviors, positive expression, and self-reports of enjoyment.	37 male and 23 female; M age = 7.57, SD = 2.80 

FUNCTIONS	FINDINGS	AGE GROUP
7. HYBRID HUMANOID H3 ROBOT		
To prevent child accidents with “on demand” interaction between the robot and the child in the relevant context that the robot is used (preventing child accidents). This is achieved through an active attraction of child attention as well as passive interaction.	The combined fish eye camera in the sensorized environment and a robot onboard camera made it possible to override remotely robot’s autonomous control and allowed a very high accuracy of control. We noticed that the child was ignoring sometimes robot’s articulated words, and therefore thought that the parents’ voice (via robot speakers) would be more familiar and appeal to the child better.	1 girl aged 3 years, and her mother, 
8. ICAT		
A peer or co-learner, which adopts empathetic behaviours towards the child [19 - where children play chess two hours per week as part of their school curriculum.	The results showed that children perceived the robot as more engaging and helpful and also provided higher ratings in terms of self-validation.	26 Portuguese elementary school ages between 8 and 10 years old. 
9. INFANOID		
Infanoid has two hands, each of which has four fingers and a thumb that are capable of pointing, grasping, and a variety of other hand gestures; it also has lips and eyebrows to produce various facial expressions, like surprise and anger.	The children changed their ontological understanding of Infanoid in recognizing the robot as a moving thing, then as an autonomous, subjective system that possesses attention and emotion as an initiator of the motion. They also recognize the robots as an intersubjective companion with which they can exchange or coordinate their attention, emotion, and actions.	14 normally developing children (about 5 years old on average). 

FUNCTIONS	FINDINGS	AGE GROUP
10. IROBI		
Irobi robot is a commercial robot which can offer different services including remote interactive communication and guarding for children.	iRobi marked the students' attendance and used a face recognition program to ask children about their mood.	Pre-school children in the city of Daejeon, South Korea. 
11. KEEPON		
The creature-like robot, Keepon (pronounced, "key-pong") is designed to perform emotional and attention exchange with human interactants (especially, children) in the simplest and most comprehensive way.	0-year-olds: The interaction was dominated by tactile exploration using hands and mouth. The babies did not pay attention to Keepon's attention. 1-year-olds: The babies showed awareness of Keepon's attentional and emotional expressions. Some mimicked the robot's emotional expressions (by rocking and bobbing their bodies). 2-year-olds: They socially interacted with Keepon by showing toys. When the robot's response was meaningful to the babies, they often soothed the robot by stroking its head (See Fig.).	23 normally developing babies in three different age groups, namely 0-year-olds (from 6 months of age), 1-year-olds, and over-2-year-olds, 
12. KIBO ROBOTICS KIT		
A tool for children to acquire specific learning goals such as programming skills to solve problems and tinker with technology.	The children displayed greater concentration in completing their tasks and would persevere even on difficult challenges. They also were keener to problem-solve using the toys and tried to help their friends to find solutions.	35 children from Play@TP, an experimental kindergarten in Temasek Polytechnic, Singapore. 

FUNCTIONS	FINDINGS	AGE GROUP
13. KIWI ROBOTICS KIT		
A tool for children to acquire specific learning goals such as programming skills. On a basic map on the floor, children programmed their robots to go from point A to point B using number parameters	Results show that beginning in pre-kindergarten, children were able to master basic robotics and programming skills, while the older children were able to master increasingly complex concepts using the same robotics kit in the same amount of time.	N = 60 children in pre-kindergarten through second grade from an urban, public, early education school that serves children in Pre-K through third grade in Boston, Massachusetts 
14. NAO		
NAO as a dance robot tutor with children in the context of creative dance	In general, the children responded in a very positive way. They liked the robot and the way it moved. They engaged with the robot copying or creating movements and they understood the movement concepts.	17 children divided in four groups between 8 and 9-years-old 
15. PAPERO - "PARTNER-TYPE-PERSONAL-ROBOT		
Papero. It is capable of recognizing and verbally communicating with people, sending images by mobile phone to persons far away, as well as playing games and singing along with others.	Nil	Nil 
16. PEPPER		
Used in collaborative play and interactive storytelling	A report documenting the usage scenarios, challenges and considerations, as well as the benefits for preschoolers and teachers will be produced. This will provide insights on how we can extend and scale the use of robots to more pre-schools in the future.	2 pre-school centres; My First Skool Jurong Point and MY World @ Bukit Panjang 

FUNCTIONS	FINDINGS	AGE GROUP
17. ROBOTIC PUPPETS		
Robotic puppets as playtools found inside a classroom that would be able to (1) rotate its body horizontally, (2) rotate its head vertically and (3) open and close its mouth by rotating the upper jaw.	The results of the study indicated that when playing with the robotic puppets, the performance of the children with respect to thinking and learning, creativity and imagination, and social interaction and independence, is comparable to other traditional playtools.	52 children aged 5 to 6 years, from 2 community-based kindergartens in Singapore, 20 from the first (9 girls and 11 boys (same class) and 32 from the second (16 girls and 16 boys (3 separate classes). 
18. ROBOVIE		
A humanoid robot capable of human-like expressions and recognizes individuals using ID equipment (robot peer and partner - 2 interactive humanoid robots that only speak English in a Japanese elementary school to imitate the arrival of an international transfer student to encourage foreign language study	Children enjoyed interacting with the robot, and some even expressed sympathy for it. The authors believe that this is one of the first studies that provides evidence of children rapidly adapting to an interactive humanoid robot and developing relationships with it.	6-7 years old, 59 boys and 60 girls); 11-12 years old, 53 boys and 56 girls. 
19. TEGA ROBOT		
A social robotic learning companion created for a particular learning task - The robot and the virtual agent each took on the role of a peer or learning companion and accompanied the child on a make-believe trip to Spain, where they learned new words in Spanish together.	The key lessons learned about conducting child-robot interaction research in children's preschool classrooms were as reflected in the teachers' feedback. For e.g. Consider how the activity can complement curricular goals.	3 "special start" preschool classrooms at a public school in the Greater Boston Area; 34 children ages 3–5, with 15 classified as special needs and 19 as typically developing.