MOBILE ROBOTS ENGAGING CHILDREN IN LEARNING

F. Michaud[1], T. Salter[1], A. Duquette[2], H. Mercier[2], M. Lauria[1], H. Larouche[2], F. Larose[2]
[1]*Dept. Elec. Eng. & Comp. Eng.*, [2]*Dept. Preschool and Primary Education*
Université de Sherbrooke, Sherbrooke (Québec) CANADA J1K 2R1

INTRODUCTION

Mobile robots are machines that can move and act in the real world, making it possible to generate a multitude of interplay situations, which can engage children and encourage interaction in a variety of different ways. Mobility, appearance, interaction modalities (e.g., sound, light, moving parts) and behaviour (predetermined and adaptive) can all have an influence in sustaining the interest (and therefore learning) of typically developing children or children with specific deficits such as autism. This paper summarizes findings from two of our on-going projects, one using a spherical mobile robot and the other using a humanoid-like robot toy.

ROBALL, A SPHERICAL ROBOT

Shown in Figure 1, Roball is a spherical robot constructed using a plastic sphere (bought in a pet store). It consists of two halves that are attached to each other [6]. It is 6 inches in diameter and weighs about 4 pounds. The robot is made of an internal plateau on which all components (motors, sensors, microcontroller, etc.) are attached. Two DC motors are located on the side of the plateau, perpendicular (on the horizontal plane) to the front of the robot. These motors are attached to the extremities of the spherical shell. Turning in the same direction, they move the center of gravity of the internal plateau forward or backward, for longitudinal motions. Steering is achieved using a counterweight (a 12V 1.2Ah nonspillable rechargeable SLA battery) mounted on a servo-motor. Tilt sensors are used to provide inclination measures for longitudinal inclination and lateral inclination.

Using this spherical mobile robot, we conducted different types of studies, which have involved varying research agenda's, such as evaluating the influence of autonomous motion on children between 12 to 18 months old [8]. Here we discuss a study which developed an algorithm with the ultimate aim of adapting the robot's behavior to a child's interaction based on perceived interaction using proprioceptive sensors. Roball's proprioceptive sensors consist of three accelerometers, one for each axis (X, Y and Z), and three tilt sensors, one for left tilt, one for right and one for forward/backward tilt. The configuration of the tilt sensors allows the detection of either left or right tilt with both sensors giving the same value, and also allows detection of rotation with readings from the sensors giving opposite left/right tilt values due to centrifugal acceleration.

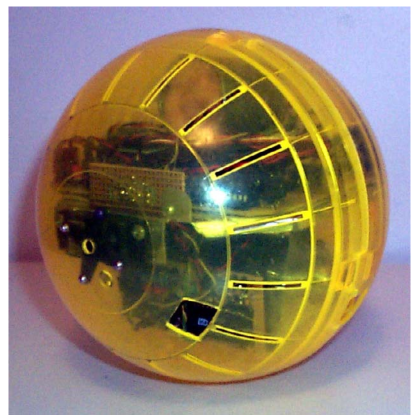

Fig. 1 – Roball

This study involved different sets of trials. Trials were conducted both with and without children. The function of the robot during all of the trials with children was to act as a moving toy, to engage the child and encourage interaction.

The first set of trials involved a series of laboratory experiments, followed by a second series of trials held at both a playgroup and a school setting. The laboratory experiments were used to investigate whether measurements from these two different types of proprioceptive sensors could record things such as jolts to the robot, the robot receiving general interaction, the robot being carried or the robot being spun. The trials conducted in a playgroup and school setting were used to confirm laboratory sensor readings were also found when the robot was applied in real life environments. These trials showed that it is possible to detect different environmental conditions through the analysis of proprioceptive sensors (accelerometers and tilt) [13,14].

After analysis of the sensor readings from these two initial set of trials it was decided to develop an algorithm that could classify the readings coming from the on-board sensors into zones which detect four modes of interaction: *Alone*, *General Interaction*, *Carrying* and *Spinning*. A fifth condition, named *No Condition*, is necessary for situations that can not be classified. We then developed an algorithm based on the five heuristic rules derived from this analysis [13,14]. The algorithm uses a temporal window of 4 seconds to calculate an average of the sensor readings and thus derive which condition it believes the robot is currently experiencing. This window is moved forward in time by 0.10 sec increments.

A third set of trials, without children, (3 per each mode of interaction, lasting 4 minutes each) were conducted at the laboratory to test the algorithms ability to detect the four different modes of interaction: 1) the robot is alone; 2) the experimenter stimulates general interaction; 3) the experimenter carries the robot; 4) the experimenter spins the robot. Roball was able to identify *Alone* (97%), *Carrying* (92%) and *Spinning* (77%) with reasonable accuracy. However, identifying *General Interaction* (10%) was more difficult. Probable causes for this are that at times the robot is in fact spinning or alone during the Interactions trials. Such conditions would therefore be identified under the corresponding categories.

Following on from developing the algorithm, we used the algorithm to add adaptive behaviors to the robot. In total, three adaptive behaviours were added to the robot: two behaviours involved vocals and one behaviour involved motion coupled with vocals.

1. When the robot classifies its sensor readings as SPINNING the robot produces the sound: 'weeeeeeeeeeeeee'.
2. When the robot classifies its sensor readings as CARRYING it stops all motion and says 'put me down'.
3. When the robot classifies its sensor readings as ALONE it says 'play with me'.

A fourth set of trials was conducted with children in a real life setting to test the effects of adaptation. During its interactions with the children, the robot did for the most part respond appropriately. The other notable observation from this study and all those preceding it was that there was an increased level of interest and engagement from the children. However, It was noticed at times that the robot did not react correctly, in particular the robot often thought it was being carried when it hit the wall of the pen, causing the robot to stop and say 'put me down'. This will be corrected for the next experiments. Interestingly, as a side effect, this seemed to cause an even higher level of engagement and interaction from the children. For example, the child might look at the experimenter and say "its asking me to put it down" and then proceed to aid the robot by moving it so that it could progress on its way.

Fig. 2 – Tito, the robot mediator

TITO AS AN IMITATION AGENT

The robot Tito, shown in Figure 2, is approximately 60 cm tall and is colored, red, yellow, and blue. Its clothes are washable and made of soft material. It uses wheels to move, but its structure shows two feet and two legs. It has two arms that can move up and down rapidly, a head that can rotate (to indicate `no') and rise up (to express surprise), a mouth (for smiling), two eyes, a nose and hair (made from fiber optic cable to illuminate). Also, a small wireless microphone-camera device was installed in one eye of the robot. Different parts of Tito's body can be illuminated and it is able to sense if it is being shaken or if it has flipped over. Tito also generates vocal requests through pre-recorded messages. A wireless remote control (using a video game controller) was designed for teleoperation, and an on-board microcontroller enables pre-programmed sequences of behaviors (motion and vocal messages). Examples of pre-programmed behaviors are: moving the left arm while saying goodbye, expressing happiness by moving its arms, singing and rotating on the spot, or shaking its head to indicate 'no'. Tito records and stores internally the timing between the interactions of the child (from sensory data and according to the experimental scenarios). Tito also emits a sound when it starts the execution of an experimental scenario, allowing synchronization of video data recorded with an external camera. The activation button on Tito is hidden at the bottom of the robot so that the child is not tempted to play with it.

Since 1999, we conducted a series of experiments involving mobile robotic toys and autistic children [7]. Tito was designed to study if and how a mobile robot can, by being predictable, attractive and simple, facilitate reciprocal interaction such as imitation with autistic children. Five years old children diagnosed with low-function autism are in many ways comparable to 8-9 months old children of regular development. They will often present the same sensory interests. However, children with autism usually have sensory play patterns that are more repetitive [1], their imitation is selective and is used with an aim of increasing the stimuli [5]. They also present deficits in recognized intentional communicative imitation [9,10], in sharing attention (avoiding eye contact, lack of smiling) and conventions (poor imitation of facial expressions and gestures) for communicating common interests [5,9]. Also noted is the quasi-absence of verbal language and pretend play [1]. These deficits are explained by a difficulty in perceiving and processing stimuli from their environment, affecting comprehension of social signals (gestures, words and intentions of others) [15]. Thus, low-functioning autistic children need interventions which take account of their particular interests and their decoding deficits by a medium that is predictable and simple, able to catch their attention and easy to understand. Mobile robots show potential in this regard because they generate more interest and attention compared to static objects, and bring into play social interactions skills (visual contact, imitation) [12].

The exploratory study conducted here aims to verify that an animated object, more predicatble and less complex than interacting with humans, would make an autistic child demonstrate reciprocal communication, observed by: 1) the reduction of avoidance mechanisms, namely repetitive and stereotyped plays with inanimate objects; 2) the increase in shared attention and shared conventions; and 3) the manifestation of symbolic mode of communication like verbal language.

Our methodology consists of conducting an exploratory study following a single case protocol [4] (21 exposures, 5 min cases, 3 times/week over 7 weeks). We evaluated shared attention and shared conventions with four 5 years old low-functioning autistic children (3 boys and 1 girl) selected in the Centre de réadaptation le Florès of Laurentides, Québec, Canada. The experimental procedure we used was to expose a pair of children to Tito, the robotized mobile mediator (animated object with human-like appearance), and to expose another pair of children to a human mediator (the experimenter). Both mediators execute the same imitation plays involving imitation of facial expressions, body movements and familiar actions.

Results [2,3] show that the forms of shared conventions such as imitation of body movements and of familiar actions are higher with the two children paired with the human. This may be explained by the children diagnosed with low-functioning autism having more difficulty in understanding the communication intent from the limited motion capabilities of the robot. It is possible that a robot having arms that have higher degrees of freedom may have helped with this understanding. Imitation of words only appeared for one participant, who was paired with the human mediator. We can however report that the two children paired with the robot demonstrated:

- More frequent shared attention by having more visual contact and proximity compared to the children paired with the human mediator. This confirms the hypothesis that shared attention is facilitated by the appealing characteristics and predictability of the robot. In fact, when the robot expressed emotions of joy and sadness or made simple actions, the autistic children reacted to the voice intonation. They also reacted to the lights that represented emotions and the simple slow motion of the robot, by looking and moving towards the robot. Tito was designed to facilitate decoding of these interaction cues by the autistic children.
- Reduced repetitive plays with inanimate objects of interest (their favorite toy), and no repetitive or stereotyped behavior towards the robot. These reduced behaviors can be explained by the interest children have for the sensory properties of the robot (movements, colors, lights). Their attention is focused on the robot rather than on the inanimate object.
- More imitation of facial expression of joy (smiling). The results are possibly explained by the ease of understanding the expression of the robot (illuminated smile). Emergent interactions were noted with the pre-verbal autistic child and the robot through imitation of gestures (handing back the hat, pointing at the door, waving good bye). There was also imitation of motor noises at the same rhythm as the robot (more specifically when the robot was waving when saluting). Furthermore, the child reproduced the same posture as the robot (e.g., by kneeling).

Further study of the video footage of the trials revealed that the robot appears to be an interesting way in helping children initiate contact, something that typically developing children can do when meeting strangers. The children that were paired with the robot first created a distance with the robot, allowing them to initiate interactions such as eye contact and smiles.

Then, the children moved closer to the robot, enabling them to continue interacting with the robot. Despite at times the children displaying ritual behavior and at times also leaving the communication area, which can be associated to an avoidance behavior, they did so as part of a familiarization process as described by Ricard and Gouin-Décarie [11]. This pattern was not observed with the children paired to the human mediator, nor did we see behavior associated with a familiarization process.

Finally, another interesting observation is that children eventually made the discovery that Tito was teleoperated, which generated enthusiastic interactions between the child and the experimenter. This concurs with Robins et al.'s [12] observation that a robotic device reveals to be an interesting intermediate between the child and an educator.

In conclusion, this study helps us to understand the processes for decreasing autistic children's anguish and increasing their attention to learn certain forms of communication. Our results are very encouraging and support the continuation of work on this research question, repeating the trials with a greater number of subjects to consolidate these conclusions.

CONCLUSION AND FUTURE WORK

Mobile robots as assistive technologies are a rich source of novelty in creating interplay and learning situations, allowing implicit or explicit adaptation to children and the environment, helping keep children engaged. Findings from these experiments confirm the engaging factor mobile robots generate with children, leading us to prepare more experiments in natural living environments. We plan to measure the predominant factors required to sustain interest, and to compare observations of normally developing children and children with autism.

At the same time, conducting trials with children and mobile robots is highly challenging, with a great set of factors (hardware, software, human, environmental) influencing the process and results. Robot design and conducting rigorous experimentations with people are two very demanding tasks, critical in making solid scientific contributions with concrete benefits. For efficient and fulfilling efforts in doing such work, it is important to start small and increase the complexity of the experiments (e.g., test population size, robot's capabilities, experimental methodology).

For our future work, to enhance the interaction modalities between the robot and the children, we are also developing a robotic arm using variable impedance actuators, capable of safely interacting with children, and an embedded sound source localization and separation device for real-time tracking of vocal interaction.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of the Canada Research Chair (CRC - held by F. Michaud), FQRNT, NSERC and CFI, in support of this work, in support of this work. Parts of this paper are also presented at the American Association for Artificial Intelligence (AAAI) Spring Symposium on Socially Assistive Robotics, March 2007, Stanford.

REFERENCES

[1] Blanc, R., Gomot, M., M.P. Gattegno, C. Barthélémy, J.L. Adrien, Les troubles de l'activité symbolique chez des enfants autistes, dysphasiques et retardés mentaux et l'effet de l'étayage de l'adulte. *Revue Québécoise de Psychologie*, 2002.

[2] Duquette, A., Michaud, F., Mercier, H., Exploring the use of a mobile robot as an imitation agent with children with low-functioning autism, submitted to *Autonomous Robots*, Special Issue on Socially Assistive Robots, 2007.

[3] A. Duquette, L'exploration d'une intervention avec un robot-jouet animé chez les enfants autistes, Master's thesis, Department of Psycho-Education, Université de Sherbrooke, 2005.

[4] Kazdin, A.E., Statistical analayses for single-case experimental designs. *Single Case Experimental Designs*. Eds Hersen and Barlow, 1976.

[5] Lemay, M., *L'autisme aujourd'hui*. Paris:Éd. Odile Jacob, 2004.

[6] Michaud, F., Caron, S., Roball, the rolling robot, *Autonomous Robots*, 2(12):211-222, 2002.

[7] Michaud, F., Salter, T., A. Duquette, and J.-F. Laplante, Perspectives on mobile robots used as tools for pediatric rehabilitation, *Assistive Technologies*, 19:14-29, 2007.

[8] Michaud, F., Laplante, J.-F., Larouche, H., Duquette, A., Caron, S., Masson, P., Autonomous spherical mobile robotic to study child development, *IEEE Trans. on Systems, Man, and Cybernetics*, 35(4):1-10, 2005.

[9] Nadel, J., Imitation and imitation recognition: Functional use in preverbal infants and nonverbal children with autism. *The Imitative Mind Development Evolution and Brain Bases*. Eds Meltzoff and Prinz, 2002.

[10] Nadel, J., Revel, A., Andy, P., Gaussier, Ph., Toward communication, first imitations in infants, low-functioning children with autism and robots. *Interaction Studies*, 5(1):45-74, 2004.

[11] Ricard, M., Gouin-Décarie, T., L'humain et l'inanimé pour l'enfant de 9-10 mois. *Enfance*, 45 (4), 351-360, 1990.

[12] Robins, B., Dauthenhahn, D., R. te Boekhorst, A. Billard, Effects of repeated exposure to a humanoid robot on children with autism. *Proc. Universal Access and Assistive Technology*, 2004.

[13] Salter, T., Navigational and proprioceptive sensor-based recognition of interaction patterns between children and mobile robots, Ph.D. Thesis, Univ. Hertfordshire, 2006.

[14] Salter, T., Michaud, F., Létourneau, D., Lee, D.C, Werry, I.P., Using proprioceptive sensors for categorizing interactions, *Proc. Human-Robot Interaction*, 2007.

[15] Zilbovicius, M. Imagerie cérébrale et autisme infantile. *Revue Cerveau et Psychologie*, 2004.