Social Robots in Postural Education: A New Approach to Address Body Consciousness in ASD Children

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Abstract. Autism Spectrum Disorders (ASD) represent one of the most prevalent developmental disorders among children with different level of impairments in social relationships, communication and imagination. In addition, impaired movement is also observed in individuals with ASD and recent studies consider this factor as a limitation for fully engagement in the social environment. In the present work, we propose a new approach to promote postural education in autistic children with the involvement of a humanoid social robot and the therapist in a triadic interaction environment to better understand their motor development and body consciousness.

Keywords: Autism, children, social robot, postural education, human-robot interaction, game.

1 Introduction

Autism Spectrum Disorders (ASD) are now one of the most prevalent developmental disorders among children. Autistic children exhibit a wide variety of behaviors and developmental levels, from repetitive, ritualistic and stereotyped behaviors (RRBs) of posture and part of the body (e.g. hand flapping, rocking, swaying, ...), to limit in imagination, communication, to self-hetero-aggressive intent, lack of flexibility or hypersensitivity to anything that involves changes in the surrounding. However, difficulty with engagement, attention, and appropriate behavior in the classroom are common and interfere with students' ability to participate in the educational mainstream [1].

In addition to the main three core symptoms, impaired movement is commonly observed in individuals with ASD. In fact, it has been found that ASD individuals display atypical movement patterns during locomotion, reaching and

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aiming [2]. Research suggests that the postural system in individuals with ASD is immature and may never reach adult levels, which can be a limiting factor on the execution of other motor skills, such as coordinated hand/head movements and inhibition of reflexes, and may constrain the ability to develop mobility and manipulatory skills. The origin of this lack in motor coordination in ASD individuals seems to be related to the relationship between mirror neuron system (MNS) activation, responsible of motor coordination and social skills, and the development of autism.

1.1 Motivation

The human-robot social interaction has become a popular research field in recent years. There are many robotic platforms that serve the goal of developing human-robot social interaction and there are numerous researches indicating robots can be used as a therapy medium to assist children with special needs [3]. In particular, early intervention is critical for the children inflicted with autism in order for them to lead productive lives with a higher degree of independence in their future years.

Several activities play an important role in child development. According to the International Classification of Functioning and Disabilities Version for Children and Youth (ICFCY), the World Health Organization remarks that the game play is one of the most important standpoints for a child in his/her life [4]. In fact, playing contributes the development of children by advancing their social skills, as well as their communication skills and also sensory and motor skills. Through the game play, children recognize their social environment and establish the necessary relationships.

On the other hand, education is considered the most effective therapeutic strategy. More specifically, computers in the education and therapy of people with autism has demonstrated to be beneficial for the development of self-awareness and self-esteem. In recent years, software-based systems include highly structured virtual environments [5] have been used by therapists and teachers as tools in order to teach social and other life skills (e.g. recognizing emotions, crossing the road, learning where and how to sit down in a populated cafeteria). However, interactions with an interactive physical robot can contribute important realtime, multimodal, and embodied aspects which are characteristic of facetoface social interaction among humans [6]. We believe that sharing the space with a robot is a motivational resource that aids the child to effectively engage in the task as opposed to a virtual character in a screen [7].

In this scenario, SARACEN (Social Assistive Robots for Autistic Children EducatioN) and KISSHealth (Knowledge Intensive Social Services for Health) propose a new approach to promote postural education in autistic children with social robots combining expertise in Biomechanics with expertise in Computer Science and its applications. SARACEN project proposes innovative methods for early diagnosis of ASD and therapy support for autistic children with socially assistive robots. On the other side, KISSHealth Project proposes an integrated approach to face up the problems of postural abnormalities and, as first step, it promotes the development of a postural consciousness in order to prevent and moderate postural diseases.

2 Social Robotics in Postural Education

The lack of social interaction is one of the most debilitating deficits associated with autism spectrum disorder [8]. As previously illustrated, children with autism often have trouble communicating and interacting with other individuals, their interests and activities may be limited. For these reasons, therapists are key figures in the education of children with ASD and they can be seen as parts of a larger team composed by parents, teachers and professionals. Emerging applications include social robots as tools to teach skills to children with autism, to play with them and to elicit desired behaviors from them [9], [10]. In the present work, the robot acts as a mediator for educational purposes, being able to both teach the correct postural behaviors and evaluate the learning process in a triadic interaction environment. Individual repeated freeform interactions are being used as education-therapy model, that allow the child to interact with the robot with no interaction from the therapist, unless necessary, and in presence of his/her parents for a comforting presence (Fig. 1).

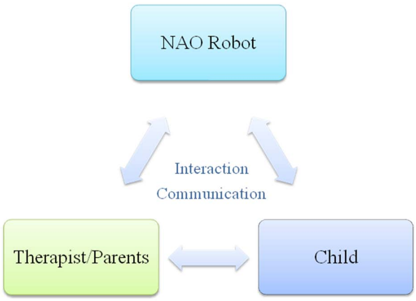

Fig. 1. Child, robot and therapist/parents interaction

The design and functionality of the robot have a significant influence on its effectiveness in therapy. Several research studies have been conducted to extract the requirements in relation to the end-user group (children with autism), categorizing robot according to appearance, functionality, safety requirements, autonomy, modularity and adaptability [11]. Considering these remarks, the NAO, a small humanoid made by Aldebaran Robotics (0.57 cm tall and 4 kg weighty), has been used. It has a total of 25 Degrees of Freedom (DoF), 11 DoF for the lower limbs, that include legs and pelvis, and 14 DoF for the upper limbs that include trunk, arms and head [12]. Furthermore, the manufacturer of NAO offers several software tools to use with the robot, as Choregraphe, an application that permit to create robot behaviors, test them on a simulated robot or directly on a real one.

The present paper represents a step forward in the application of social robots in the education of children with ASD focusing the attention to the aspects related to motor development as an essential condition to improve also in interaction and social development.

2.1 The Postural Education Application

The concept of education refers to the process of helping children in development and growth, giving them skills that they will use throughout life. For children with special needs, education and therapy are integrated and tailored to the needs of the individual child in order to achieve the child's physical, mental and social development [13]. In this sense, the play scenarios cover all the important domains of childrens development (intellectual, sensory, communication, motor, social and emotional [14]) and they can be used to provide different experiences and possibilities for developing aspects in all the developmental domains.

In this paper, we focused our attention to motor development, that includes all aspects of controlling the body, its muscles, and its movements. To fully engage in social interaction, an individual requires a full repertoire of movement behaviors for use in communication and for understanding the communicative nature of others' movements [2]. In this sense, posture can be considered the first step in improving childs abilities because of its importance for both gross and fine motor functions.

2.2 System Architecture

In the play scenario, we developed three levels of complexity including a teaching phase, a reinforcement phase and a game phase. During the teaching phase, the child was introduced with the robot and he/she familiarized with the body parts. The robot is provided with several lessons on human body composition, in relation to its principal components, as head, trunk, arms and legs that the robot shows with its own robotic body (in Fig. 2 some examples), and on human body posture when sitting, standing, bending and handling. As the robot is quite small and due to its kinematic limitations, some postures were unnatural so to support the process of knowledge, an inhouse cartoon is simultaneously projected on a monitor, that highlights figures and words the robot is talking about. Then, the child has reinforced and improved his/her performance with body posture by repeating them with the robot. The robot was configured to wait for the child to show the correct body part using the cards he/she has on the table. Finally, the child and the robot played an interactive game using the information he/she has acquired in the learning process.

The autonomous system is implemented through different software modules, that correspond to the designed levels:

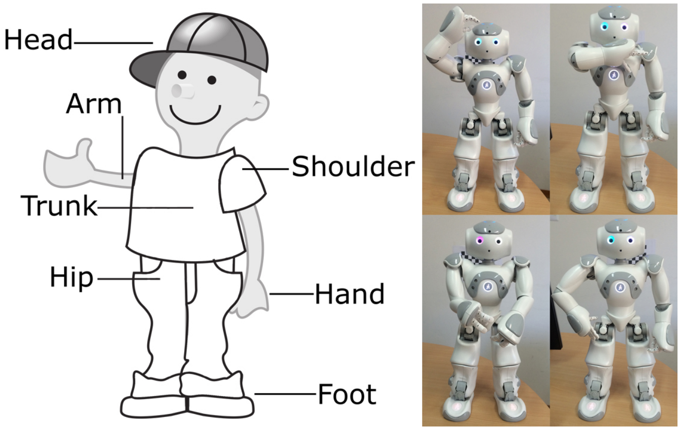

Fig. 2. The robot shows the human body parts: head, shoulder, hand, hip

1. Presentation module: the robot shows up and explains the purpose of the lessons and asks if the child is ready to begin;
2. Lesson module: the robot explains some fundamentals of human body, correct and wrong postures; the robot uses verbal and gestural communication and it shows the correct and incorrect postures;
3. Random choice module: the robot randomly chooses a body posture from postural lectures;
4. Ask module: the robot asks the child to pick a figure;
5. Recognize module: computer vision algorithms recognize the figures selected from the child;
6. Compare module: algorithms compare the figure picks from the third module with the child's one. If correct, the robot communicates it to the child; otherwise, it communicates the inaccuracy of the selection;
7. Ask module: the robot ask the child if he/she wants to play again go to the next lesson. If the child wants to play again, the system restarts with random module, otherwise the system call the lesson module.

The serious game, developed through the modules 3, 4, 5, 6 and 7, is necessary to reinforce the acquired information in an enjoyable way and to engage the children attention.

2.3 Experimental Methods

Participants. The target group in our experiments is the autistic children but we tested the designed approach with adults as a first step. It was performed with ten volunteers (5 female, 5 male). All participants were graduate students and the ages were distributed in the range of 2533 with the mean $\mu = 28{,}6$ years and standard deviation $\sigma = 2{,}17$. None of the participants had any specific postural knowledge prior to the experiments. An ongoing experiment involves a group of twenty typically developing children (1113 years old) that have followed the "Postural Education at School" Project (the PoSE Project) implemented by the KISSHealth Project in the "MaterdonaMoro" Middle School of Mesagne. The preliminary results of this experiment will provide a guideline for more suitable experiment design in interaction between humanoid robot and children.

Material. The setup of the room used in the experiment is depicted in Fig. 3. The interaction takes place in the experiment room and the operators remain in the same room to deploy the overall system and operate the robot when required because the robot behaviors are completely autonomous. The therapist is close to the child and it acts as a support/encouragement while the main learning is done between the robot, TV screen and the child.

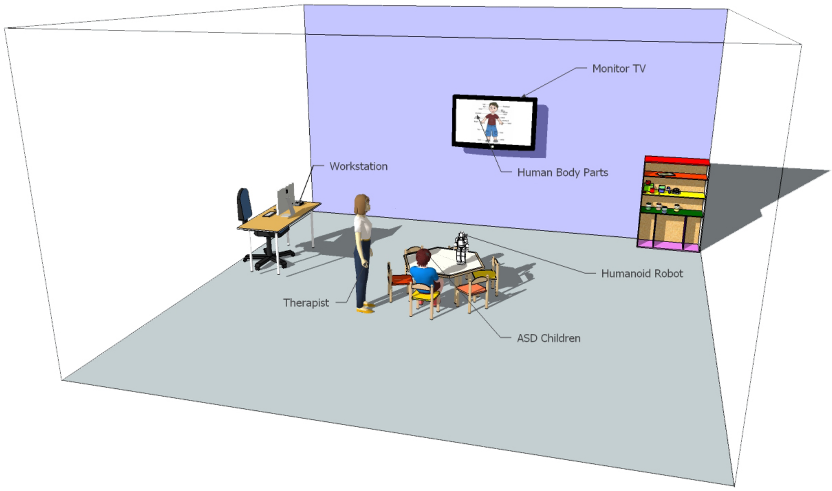

Fig. 3. An overview of the proposed scenario promoting a triadic interaction: the child, the therapist and the robot are involved in the session to both learn the required skills and generalize them to the people around him/her

In preliminary tests, the setup was prepared in the KISS-Health Laboratory located in the "San CamilloDe Lellis" Hospital of Mesagne. The scenario consisted of a 46" TV screen on which a video about the essential behaviors for a correct body posture, previously recorded, was projected; the NAO robot; the participant and the research team. The NAO robot was placed almost 0,5 m away from the participants on the table to avoid physical interaction.

Evaluation. The interaction was qualitatively assessed through selfreported measures based on the survey presented to the participants after the session. Each participants filled out a questionnaire which ranks the three phases of the educational program on a 15 Likert Scale. The possible answers were: strongly disagree, disagree, neutral, agree and strongly agree. It has been argued that using classic questionnaire with children does not always provide reliable feedback [7]; thus alternative tools will be used to explore the childrenrobot interaction.

3 Preliminary Results

It is important to emphasize that the preliminary experiments were performed in order to perfect the framework of proposed game before performing these tests with ASD children. Informed consents were collected for all the participants involved in the study. The proposed scenario was tested with ten graduate students without any prior knowledge of postural education. In this study, twenty cards of correct/wrong postures were proposed by the humanoid robot in order to test the participants.

The participants followed the lesson related to the body posture and then they were asked to recognize the correct or wrong card according to the request of the NAO robot. To evaluate the proposed scenario, a survey was presented to the participants reported in Table 1. To avoid social desirable responses the

Table 1. Participant's selfassessment through classic questionnaire of 15 Likert Scale

Questions	strongly disagree	disagree	neutral	agree	strongly agree
The educational program was clear.	0	0	1	2	7
The contents were appropriate for children.	0	1	3	5	1
The game was interesting.	0	0	2	7	1
The body motions of the NAO fitted what it was talking about.	0	0	0	4	6
The body postures of the NAO were clear to see.	0	1	3	6	0

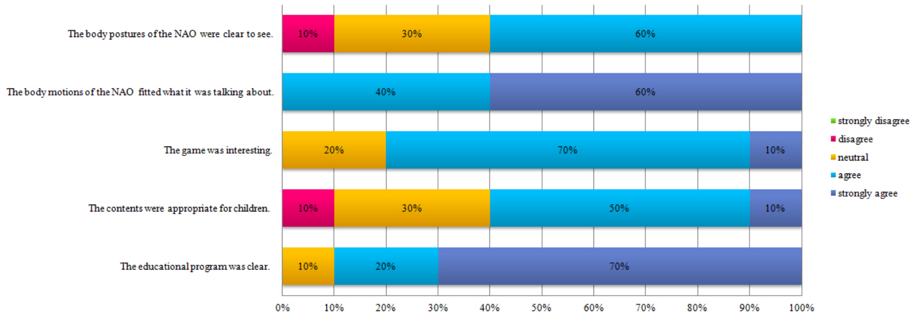

Fig. 4. Stacked Frequencies of 5categoryLiker Scaleitems

questionnaire were all anonymous. To ease the interpretation of the results, we display the distribution of observations in a bar chart measuring the frequency of the categories selected by the participants and illustrated in Fig. 4. The outcomes show how thirty nine of the fifty possible items are in agree with the statements in the survey, nine assume a neutral attitude under investigation and only two are in disagree with our assertions. More detailed experimental data, relative to the sample of typically developing children, are still ongoing and they will be presented in subsequent works.

4 Discussion

The purpose of conducting child-robot interaction sessions is to enable the children to overcome their deficiencies and gain a better understanding of the world in relation to their social skills, emotional awareness, and their communication with the environment and people around them. In this proposed scenario, the attention is focused on improving the children's movement development and body consciousness. To achieve these objectives, educationtherapy sessions are composed of activities that can result into positive behaviors from children with autism. Here we consider a triadic interaction, which is one that involves a child, a robot, and another companion, in this case the therapist.

Some authors [15] have highlighted the anecdotal results of introducing robots into experiments or therapeutic sessions with ASD individuals, but overall preliminary results suggested that the game-based approach for the children to learn, understand and correctly guess the emotions shown by NAO has been a success. Hence, a humanoid with moderate likelihood to actual human does have potential to teach children with autism about head and body postures that are associated with certain feelings or emotions. Consequently, a robot in human shape is a salient mediator to teach emotions to the children and this can easier be transferred from child-robot to human-human interaction in actual social scenarios [10].

These considerations suggest us that the proposed approach might be helpful with children with ASD in terms of:

- Sensory Problems. Many children with autism have difficulty with multiple sources of sensory input. The envisioned method can isolate specific stimuli and allows subjects to control how much they will experience.
- Lack of generalization. Difficulty generalizing behaviors learned in a single setting to similar appropriate situations limited treatment efforts in autism. Postural aspects involve a lot of daily life tasks and this can help subjects to recognize the correct situations.
- Visual thought patterns. Visual support for early learning has been effective for teaching young children with a range of special needs [16]. The proposed method seems to be an appropriate modality for people with autism and should give them an excellent opportunity for learning new concepts and behaviors.

– Responsiveness with computer technology. Although computers have not been adapted by special education programs as quickly as some would like, there is increasing evidence that they represent an effective new approach to education and learning for children with developmental disabilities [17].

Although a number of research issues need to be solved, we believe that the multidisciplinary approach here promoted develops a new experimental setting that can integrate interactions between children with ASD and robots, with the aim of analyzing and improving childrens behaviors. To our knowledge, no systematic empirical research exists addressing the question of how posture is perceived by autistic children. Our research builds on a larger body of theoretical and empirical work concerning socially interactive robots and their applications in therapy and education for autistic children.

5 Perspectives and Ongoing Work

Future developments will investigate the reliability and efficacy of the proposed method, drawing a comprehensive set of therapeutic and educational objectives in a closed loop with both therapists and teachers. An experimental study involving subjects of children with autism and typically developing children is underway. Current modules presented in this study will be improved based on inputs from medical experts. In the future, instead of randomly choosing the body posture lecture with equal probabilities, it will be chosen with some probability based on the child's downfalls, i.e. if their neck is the main issue, then it is more likely lectures will be on the neck (e.g. neck 50%, back 25%, hip 25%). Furthermore, future researches will also assess the possibilities to extend the solution here adopted to a school-based environment.

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