A Hybrid Approach Based on Multi-sensory Stimulation Rooms, Robotic Assistants and Ontologies to Provide Support in the Intervention of Children with Autism

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Abstract. Recent studies and estimates provided by several agencies such as the World Health Organization (WHO) claim that the number of cases of children and young people with Autism Spectrum Disorders (ASD) has increased in last years. In general, the affective environment of a patient with ASD is affected due to several factors related with patient's behavior and his/her affective relation with their parents and relatives. Hence, in this paper we present a comprehensive approach to support the psychological and therapeutic intervention on children with ASD. Our proposal relies on integrative ecosystem that combines knowledge modeling tools (ontologies) with intelligent ICT tools (robotic assistants, multi-sensory stimulation rooms). With this hybrid approach, it is possible providing an effective intervention process not only for patients with ASD, but also parents and relatives of those patients. This proposal has tested in two stages, a first one with 47 children without autism, and a second with the support of 36 children with ASD and 5 specialists of CIMA Foundation. The results show high levels of acceptance in both children and specialists.

Keywords: Autism Spectrum Disorders · Robotic assistants · Multi-sensory stimulation room · Ontologies · Children

1 Introduction

The Autism Spectrum Disorders (ASD) constitute a group of complex brain development disorders. According to the World Health Organization (WHO) 1 of each 160 children presents ASD. Some studies point that in last years the prevalence of ASD has increased (especially in developing countries). Commonly, the children and youth with ASD present problems in their behavior as well as difficulties to develop social skills and ability of establishing communication mechanisms with their peers. The WHO claims that evidence-based psychosocial interventions, such as behavioral treatment,

G. Di Bucchianico and P.F. Kercher (eds.), *Advances in Design for Inclusion*,
Advances in Intelligent Systems and Computing 587, DOI 10.1007/978-3-319-60597-5_45

can help to reduce difficulties in communication and social behavior, with a positive impact on wellbeing and quality of life [1].

In this line, it is important to mention that robotic assistants as well as the multi-sensory stimulation rooms have achieved excellent results in the intervention process of patients that present different kind of mental and behavioral disorders.

On those grounds, in this paper we present a hybrid approach to support the intervention process of children with ASD. Our proposal uses multi-sensory stimulation rooms with two objectives: (i) to provide relaxation activities for parents or relatives in charge of children with ASD and (ii) to conduct rehabilitation exercises for the patients. With the aim of providing a better process of rehabilitation for patients, the room has a remote control (mobile application) and can automatically adapt the color and intensity of lights as well as the volume of auditory stimuli provided for each patient. Another important service provided by the room is a functionality to generate therapy plans according to patient's profile. In order to perform the adaptation of the room and generate therapy plans, our approach uses an intelligent module that relies on an ontology and a knowledge base (RDF triplestore). On the other hand, the robotic assistant is a complement of the Multi-sensory Stimulation Room (MSR), and provides support to carry out several rehabilitation and educational activities. Some of the most relevant characteristics of the robotic assistant are described below:

- Has several costumes to adapt its appearance to children's preferences (animals, persons, characters, etc.).
- Can provide kinesthetic stimuli for children (according to their profile).
- Can be controlled remotely and includes a display (tablet) where are presented multimedia activities and games.
- Provides several imitation activities to support the development of social and communication skills.

Our approach has been put to test in Cuenca, Ecuador with 36 children and 5 specialists of the CIMA Foundation, a specialized center in treatment of children with ASD.

The rest of the paper is organized as follows. In Sect. 2 we present some relevant contributions based on ICT tools that are aimed in providing support to psychological diagnosis and/or intervention stages for children with ASD. The system architecture as well as the different elements that constitute it are described in Sect. 3. Section 4 presents the main results of the pilot experiment carried out in Cuenca, Ecuador. Finally, Sect. 5 presents some ideas for discussion and future work.

2 Related Work

Several contributions focused on providing support for both psychological diagnosis and intervention on children with ASD. The most of these contributions emphasize the importance of using Information and Communication Tools (ICT) during the therapies as well as the positive results of this strategy. Commonly, children with ASD present difficulties related with social skills, so that it is essential to develop these skills during the intervention process. Currently, the robotic platforms are used more frequently during therapies provided to patients' with ASD, and as a consequence, has been possible to check that patients are more interested on the exercises and activities carried out. Likewise, the children are more likely to work with robotic assistants [2].

In this line, it is important to mention that level of acceptance of a robot by children varies from case to case, therefore, it is not possible defining a standardized robot's model and it is necessary to design each solution according to patient's needs. In this area, Soares et al. have developed the project "Technology for autistic children" with the aim of supporting the development of social skills in children with ASD. The experimentation stage of this project consisted on using the robot during the initial psychological intervention, to subsequently gradually reduce the robot participation in the therapies (until working only with psychologists) [3]. In the same are, Esubalew et al. have used a humanoid robot and a network of cameras with the aim of providing visual and auditory stimuli for children with ASD. This proposal has validated with 18 children (10 with ASD and 8 regular) between 2 and 5 years. Each therapy intervention consisted on 4 sub-sessions guided by 2 psychologists and 2 robots. The results of this contribution show higher interest levels by children side when they interact with robots [4]. However, it must be taken into account that physical appearance as well as behavior of the robot are key elements, because they define that robot is not a toy but a tutor. Therefore, the appearance and behavior of a robot are important characteristics to improve the human-computer interaction experience [5].

On the other hand, a MSR is another technology that has reached good results in the treatment of children and youth with ASD. This occurs because between 45 and 65% of children with ASD present difficulties in sensory procedures. Silva and Lara have proposed a project to work in intervention of sensory integration in children with ASD. In this contribution, the authors have applied a pilot experiment divided in two stages: in first stage, two children of 5 and 8 years with ASD have applied a test of 125 items to know the emotional state of each child before using the MSR. After of 6 months of sessions in the MSR (with two sessions of 50 min per week), the children have shown important improvements as to mood (comfort and relaxing) [6].

On the other hand, the ontologies constitute an important tool for modeling the knowledge in different healthcare areas. Currently, this technology is useful because allows to implement several kinds of interoperability and inference processes between different types of systems. An example of ontologies applied to interoperability can be found in [7]. In this project, the authors have developed a system that relies on ontologies and provides support in the communication between persons with ASD and their peers. In this system, several agents are in charge to support the communication needs of these persons, trying to help in the interpretation of messages in a chat-based environment.

3 General System Architecture

In Fig. 1 it can be seen the general architecture the proposed system. The proposed approach relies on several components and interaction elements organized in three main groups:

- **Knowledge modeling and management:** all the information managed by the system has modeled through ontologies. Likewise, all concepts related with ASD as well as therapy strategies and patient data are stores in an database that combines ontologic and relational information.
- **Robotic assistant:** is a key complement for therapy delivery. The robot is used as an intermediary between children and therapists and implements several services such as computer vision, remote control, and adaptability.
- **Multi-sensory stimulation room:** provides relaxing and therapy activities for both children and their parents. The MSR is able to adapt itself to patient's profile. Likewise, each therapy carried out in the MSR is registered in the database.

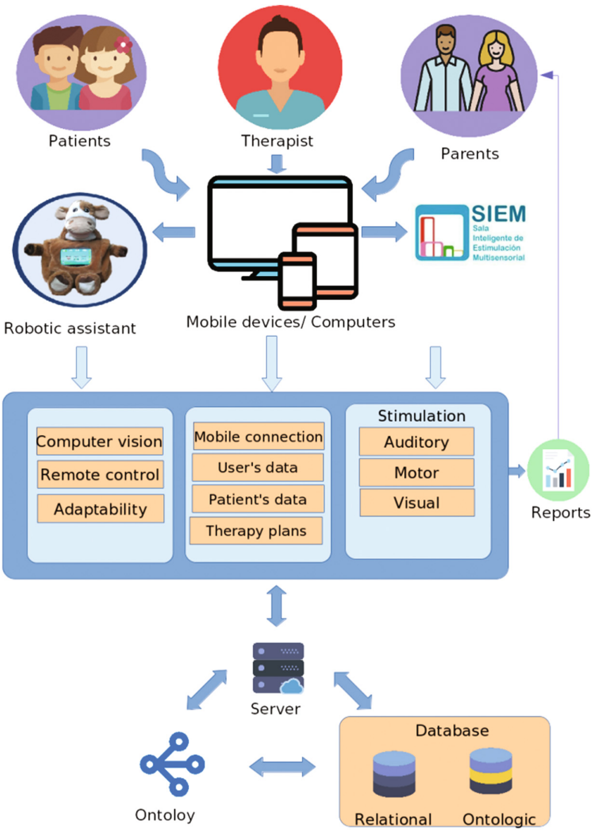

Fig. 1. General overview of the different components that constitute the proposed system, and the actors that interact during diagnosis and intervention stages.

The details of each of the components mentioned above are described in the following sections.

3.1 ASD Knowledge Modeling Through Ontologies

The ontology that we have designed relies on existing ontological models, like Friend of a Friend (FOAF) [8], and Autism Spectrum Disorder Phenotype (ASDPTO) [9] ontologies. On this basis, we have extended the functionalities and relations of these ontologies, including new elements related with the patient's profile, therapy plans, serious games, and several activities/exercises to develop the social codes. The Fig. 2 presents a partial screen capture of the hierarchical structure of the proposed ontology. As we can see, the ontology includes some classes like the following:

- Action: this class represents the interactions that occur between user and system.
- Game_Component: represents all the components used by the games modules.
- Metric: is a measure that is used to represent the most influential factors of the interactions between patients and games.

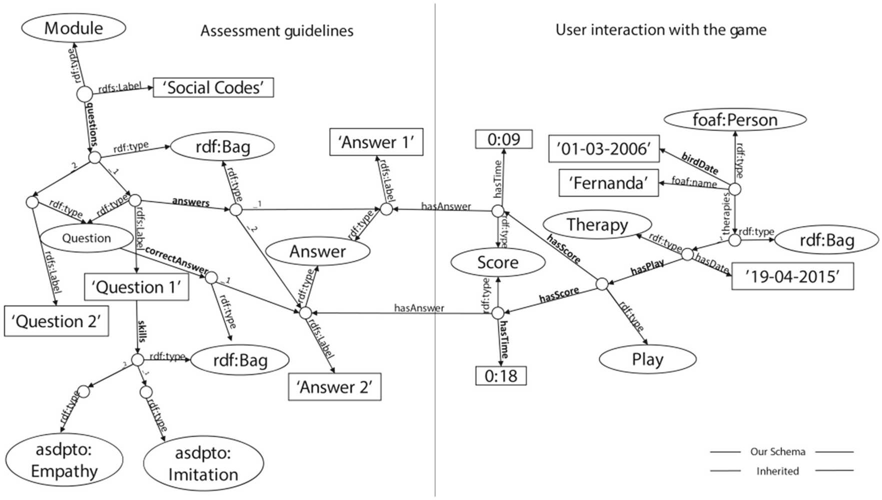

Fig. 2. A screen capture of the RDF diagram that contains two sets of elements that represent the assessment guidelines for therapy sessions (left side), and the interaction between user and games (right side)

Moreover, the ontology is organized in two main parts: the first one is focused in the representation of the game, and has modules and sub-modules (through class **Module**). These modules have several questions (class **Question**) and answers (class **Answer**). Each relation question-answer is done through object properties **answers** and **correctAnswer**. This questions are related to several factors of the **Social Competencies** (ASDPTO) through the object property **skills**. This last relation allows professionals and therapists determining which skills can be developed by patients when they interact with games.

The second part of the ontology has the aim of registering the results of different interactions between patients and games. In order to accomplish this objective, we have extended the FOAF ontology through the inclusion of the class **Therapy**.

3.2 Robotic Assistant

The robot has an anthropomorphic 3D skeleton printed from a computer-generated model. Likewise, the robot incorporates five servo-motors that allow him moving the arms, head and two wheels placed at the bottom of the structure (Fig. 3).

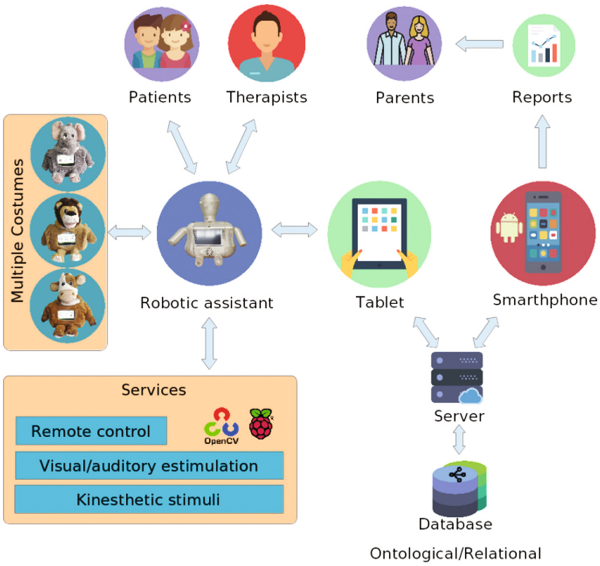

Fig. 3. General robot structure and the different services that it provides for patients and their relatives.

In order to interact with the robot, the therapists and children use a mobile device (tablet or smartphone). This mobile device allows children to response questions, play games, and monitor the therapy sessions. This information is feed to the system through the services described in previous sections. Some of the main features of the robot are described below:

- Can be controlled remotely through a web interface or an Android application.
- Has a Raspberry Pi central processor that allows robot incorporate new sensors, and control all actuators.
- Includes a Text to Speech (TTS) module to initiate dialogs with patients.
- Has different costumes to represent different kinds of animals, persons or personages.
- Is able to synchronize the activities performed with therapists or children with central web application.

3.3 Multi-sensory Stimulation Room

The MSR has several modules to conduct different kind of exercises and therapy activities. The most relevant modules as well as their main functionalities are described below:

- **Piano with lights:** this module provides exercises and activities to develop memory, attention and concentration. To this aim, it can allows creating different kinds of sequences, associating lights, animals, fruits or transport means. The piano can measure the pressure of each key with three different levels: high, medium and low.
- **Pictograms panel:** has the aim of supporting the development of visual, auditory, touch, and tactile skills. This panel has 12 interchangeable pictograms to carry out various therapy activities under different categories such as figures, colors, actions, among many others. This module implements auditory and visual stimuli for the patients.
- **Staircase of colors:** is focused on vocalization activities and is based on a set of lights that will be activated according to patient's voice volume.
- **Bubble panel:** is meant to support the development of motor, vision and touch skills. This panel has several transparent plastic panels with RGB (Red, Green and Blue) LEDs and water containers. Each container has a device that generates air to produce the bubbles.
- **Magic dice:** allows condition the color of RGB lights illuminate the room. The therapist can associate each face of die with a certain color and when the children roll the dice, the MSR automatically change its colors.

In the Fig. 4 is depicted a screen capture of the menu to change the color of the lights of MSR. As it can be seen, the therapist can create any color using combinations of the RGB color space.

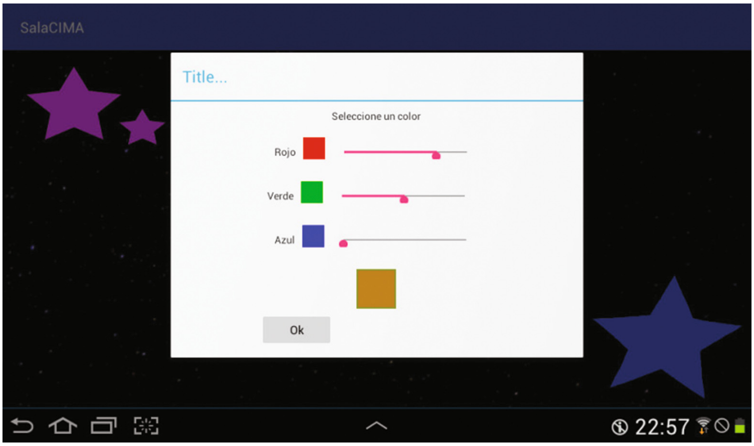

Fig. 4. A screen capture of the control menu to changing the colors of MSR lights through a RGB combination.

In the Fig. 5 we can see another screen capture of the mobile application that controls the MSR and provides therapy exercises for children. In this menu, the therapist can choose a category in which is possible to work with patients (animals, fruits, transport means, etc.).

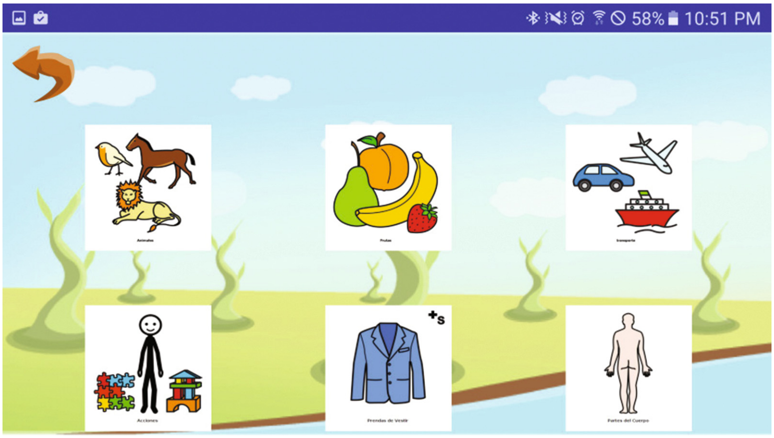

Fig. 5. A screen capture of the control menu to changing the colors of MSR lights through a RGB combination.

4 Experiment and Results

With the aim of validating our general proposal, we have conducted a pilot experiment consisting in two main stages. In the first one, we have carried out some ludic and interactive activities between 47 children of regular schools and the robotic assistant. During this stage a team of experts (psychologists and engineers) has evaluated the children response to some important characteristics of the robot, such as appearance, level of acceptance, and what kind of activities are interesting to do with the robot. In order to analyze the real feasibility of our system, we have conducted a pilot experiment organized in two stages. The 47 participants of this first stage were 27 girls and 20 boys that are attending to different schools of Cuenca city. In Table 1 we case see the number of participants according their age.

Table 1. Age distribution of children that have participated in the survey.

Age (years)	5	7	8	9	10	11	12	14
Number of participants	3	2	5	6	18	10	2	1

The first part of the Table 2 shows the number of children that think that robot and its functionalities of the robot are very good, good, average, bad, and very bad. As we can see, 41 children think that robot is "very good", whereas 6 of them think that is "good". The second part of the table depicts the children preferences according to the different costumes representing animals. As it can be seen, children prefer dogs (16 votes), cats (10), and dinosaurs (7).

Table 2. Age distribution of children that have participated in the survey.

What do you think about the robot and its functionalities?					
Very good	Good	Average	Bad	Very bad	
41	6	0	0	0	
What appearance (costume) do you prefer that robot wear?					
Dog	Cat	Dinosaur	Rabbit	Puma	Other
16	10	7	2	2	10

In the other hand, the second stage the pilot experiment had the aim determining two important aspects: the autistic children response to robot, and specialists' perception about the MSR. In the second stage, we have worked with 36 children with ASD. To this aim, we have introduced the robotic assistant in real therapy sessions with children that attend to CIMA Foundation.

Fig. 6. Children's response to robotic assistant in the following areas: interaction, level of interest, appearance, and motivation to handle.

Once the therapy session is over, the therapists have applied polls to each child with the aim of determining whether the robot had a positive impact on children. In Fig. 6 are depicted the achieved results for the following areas:

- Interaction between children and the robot: 30 were able to use the robot without assistance of the therapist.
- Level of interest showed by children: 32 were interested in the robot.
- Visual and physical appearance: 27 liked robot very much, 4 did not like and 5 did not provide a response.
- Motivation to handle the robot: 28 children were motivated to use the robot.
- Kind of costume that children prefer: the children enjoyed costumes of lion (7), cow (9), elephant (10), and no answer (5).
- The children understanding to the app commands given to him: the most of children (23) understand the commands provided by the robot through the intervention support application. On the other hand, 10 children do not understand the commands, whereas 3 did not provide an answer.

5 Conclusion

Undoubtedly, design and develop tools for people with ASD is an interdisciplinary work that requires the involvement of professionals from various fields such as health, psychology, speech therapy, medicine, computer science and electronics.

The autism allows other areas of science and engineering, robotics, computer science, etc., join efforts to achieve instruments that favor the involvement of people with ASD. This article provides an innovative system that helps psychotherapists, special educators, psychologists, family and the person with autism to improve social and communication skills.

In the same way, the proposed system is able to self-adapt to the different needs of each patient, his/her skills, and provide a personalized therapy plan. The ontologies designed in the system allow incorporating new educational contents, and express new relations of the patient's environment. The robotic assistant showed to have a very high level of acceptance among the sample. These aspects allow us establishing master lines with the objective to carrying out the same experiment with children with ASD, and determine the most relevant characteristics of the robot according to age, medical diagnosis, and related disorders.

Acknowledgments. This work was funded by the Cátedra UNESCO Tecnologías de Apoyo para la Inclusión Educativa and the research project "Sistemas Inteligentes de Soporte a la Educación Especial (SINSAE v4)" of the Universidad Politécnica Salesiana.

References

1. Organización Mundial de la Salud. http://www.who.int/mediacentre/factsheets/autism-spectrum-disorders/es/
2. Silva, S., Soares, F., Costa, S., Pereira, A.P., Moreira, F.: Development of skills in children with ASD using a robotic platform. In: Bioengineering (ENBENG), 2012 IEEE 2nd Portuguese Meeting, pp. 1–4 (2012)
3. Soares, F., et al.: Robótica-Autismo project: Technology for autistic children. In: Bioengineering (ENBENG), 2013 IEEE 3rd Portuguese Meeting, pp. 1–4 (2013)
4. Esubalew, T., Lahiri, U., Swanson, A.R., Crittendon, J.A., Warren, Z.E., Sarkar, N.: A step towards developing adaptive robot-mediated intervention architecture (ARIA) for children with autism. IEEE Trans. Neural Syst. Rehabil. Eng. **21**, 289–299 (2013)
5. Scassellati, B., Admoni, H., Matarić, M.: Robots for use in autism research. Ann. Rev. Biomed. Eng. **14**, 275–294 (2012)
6. Silva, F.C., Lara, L.: Intervención de integración sensorial en niños con trastorno del espectro autista. Rev. Chil. Terapia Ocupacional **16**, 99–108 (2016)
7. Rabello, R.D.S.: Interação e Autismo: uso de agentes inteligentes para detectar déficits de comunicação em ambientes síncronos (2010)
8. Brickley, D., Miller, L.: FOAF Vocabulary Specification 0.98. Namespace Document 9 August 2010-Marco Polo Edition (2010)
9. McCray, A.T., Trevvett, P., Frost, H.R.: Modeling the autism spectrum disorder phenotype. Neuroinformatics **12**, 291–305 (2014)