LOLY 1.0: A Proposed Human-Robot-Game Platform Architecture for the Engagement of Children with Autism in the Learning Process

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Abstract. Existing studies indicate the use of the Socially Assistive Robotic (SAR) system has enormous potential to advance therapeutic interventions in the learning process of children with Autistic Spectrum Disorder (ASD). Interactive technology, including the use of educational video games, can motivate ASD children to engage by adopting the technology as part of their communications tools. The complexity in the integration of various components of SAR linked to educational/serious games hinder the modularity and scalability of these robotic systems. This work proposes the design of an architecture for a SAR platform through the integration and reproduction of robot prototype, "Loly 1.0". Loly 1.0 has mechanical movements, audio, and gestures connected to educational games in real-time. This will support the learning process of ASD children. The robotic platform architecture design is comprised of three main parts: robot, educational game, and cloud services. A proof of concept of the SAR prototype was performed with non-ASD and ASD children. Evaluation and analysis of “synchronized operational precision between robot and video game” and “degrees of attention and usability” will be conducted. The lessons learned during the testing process will help to improve the architectural designs of hardware/software integration and connectivity. The results of reproducing a SAR prototype will be to attract the attention of an ASD child through the use a video game to engage the process of "learn by playing". This will contribute to the design of engaging and personalized Human-Robot-Interaction (HRI) and Human-Computer-Interaction (HCI) technology beneficial for inclusive education.

Keywords: robotic platform architecture, ASD, socially assistive robot, SAR architecture, learning process, serious games, educational videogames, dashboard, human-robot interaction

1 Introduction

Research related to Human-Robot-Interaction (HRI) focused on the education and health area, dabbled in the use of Social Assistive Robot (SAR) systems; seek to contribute collectively to the improvement of people's lives [1]. In inclusive education, for example SAR studies are offering the possibility of helping people with Autism Spectrum Disorder syndrome - ASD who present social, communicational, and behavioral challenges [2]. In this sense, some authors explain that novel architecture based on HRI and supported in SAR platforms can benefit children with ASD by motivating their cognitive and interpersonal communication skills [1][3][4].

On the other hand, existing literature related to Human-Computer-Interaction (HCI), indicates that the use of interactive applications (apps) games for favoring ADS people. It is argued that Serious Games or educational videogames which apply audiovisual and animated resources used for mobile devices, can helps to motivate the apathy or distraction that children with ASD in the teaching-learning process [5][6][7]. Notably, the lack of interest they may have about some areas of knowledge, can be related to Language, Literature, or Natural Sciences, but there is no a defined pattern. In this sense, educational videogames apps or serious games include animated stories, seeking to support in an entertained way the learning process of a child about curricula content they should learns as part of their primary childhood education [8]. Besides, with the intention to monitor HCI, several of the serious game productions send out traces of a child playing to a repository monitored by a control panels (dashboard platform), such as the MIDI-AM game series applications, explained by Solorzano, Sornoza, and Carrera [9].

The use of interactive technology supported by HCI and HRI can offer roles that were probably not considered working together when they were created. However, scarcity of studies was found oriented to benefit children with ASD in social and cognitive interaction by adopting novel technology assisted by SAR joined to monitored Serious Game to make it part of their communication style. Robotic intervention linked to ludic interaction can act as a catalyst that removes social pressures and increases social interactions with others [10].

This research aims to explain the testing analysis of a robotic platform’s architecture interconnected with an educational game for gather the attention of ASD children expecting to motivate their teaching-learning process.

1.1 State of Art

Research shows that there are several methods to treat the ASD in children. One of them is using technology as a therapy to improve ASD conditions. Some studies have identified an evident affinity for technology in children with ASD [7]. Specially computers applications with ludic entertainment purposes [8][9][11][12] or new technologies such as SAR intervention [1][3][4].

Technology intervention in ASD using Social Assistive Robots. Assistive Robots (AR) or SAR platforms are defined as a broad class of robot architecture proposed under the concepts of HRI with the aims to help vulnerable people around the world [3]. Several studies indicate that children with ASD tend to be motivated using technological resources that appeal their attention. SAR platforms can bring technology-assisted instruction that support the development of ASD children's social skills by providing a combination physical and audiovisual factors to encourage communication and interaction skills [1][3][4]. Authors state that visual and auditory tools reinforce education by encouraging verbal responses, interaction, and social relationships in children with ASD [7]. Furthermore, these technologies as an innovative form of therapy using technology, include the use of audio devices, visual media, computers, and robots. Their require less human effort and they are more effective in therapies [6].

Technology intervention in ASD using Serious Games. The ASD is a human condition known as psychosocial development disability difficult to treat. It does not have an organic cause, but observable behaviors and manifestations. ASD is present throughout the life of the person who has it, but a person can be assisted from the first moment that the presence of ASD is evident in a child. Delaying early intervention may represent difficulties in the adult life of these subjects [2][13].

According to López Reventós [8], in the educational field, researchers attempt to demonstrate the benefits of using educational video games or serious games in the classrooms and at home. Knowledge is developed through the academic contents of the game weft. On the other hand, cognitive abilities are expanded by the action of playing [14]. The use of interactive games to play can be a means of addressing the reluctance shown by children with ASD and an entertained way of learning academic content related to some specific topics such as Language, Literature, or Basic Sciences.

Solorzano [9] explaining the creation of a series of ludic apps MIDI-AM that monitor behavioral use and playability through a dashboard, suggest the inclusion of educational video games platforms as a means of learning. The learning is obtained because of tasks (level games challenges), stimulated by the content of animated stories that are visualized before play the game's levels. MIDI-AM apps for mobile devices use Android technology and an online dashboard platform architecture, for online data transmission in real time. The use of dashboard allows to store and present organized data for an orderly and detailed analysis of the action’s children take when using a game [9] [12][15].

HCI and HRI intervention of technology in ASD. Some research seeks to identify that through children's interest in technology, they can be approached in a different way of learning and awaken in them the motivations to learn other things. The combination of platforms using HCI and HRI by using mobile apps with AR or SAR intervention to address or encourage their correct use to play serious games can be a supporting alternative in the children’s learning process supported in this research. With this technology assistance the learning process that comes from another person, such as the teacher or tutor it becomes not too invasive for a child with ASD. For these children, too much human intervention becomes invasive since their interaction in the social aspect is affected. The use of an educational AR platform joined to monitored serious game apps such as MIDI-AM, can benefit children’s and children’s guardians to have feedback about the human-robot-game intervention. For example, information about child's attention levels and exercises (games level) interest they have the most, during pedagogical session are relevant [9], particularly to encourage learning in children with ASD.

Next section presents the design of the hardware and software architecture, called the Human-Robot-Game - HRG architecture, implemented in the Loly 1.0 robotic platform. To validate the implementation of the Loly 1.0 architecture, pluralistic research methodology tools are applied to design the process and the application. These technical tests as well as proofs of concept are carried out in section 3. In section 4, lessons learned on the implementation of the architecture are presented. Finally, the conclusions and future works are presented in section 5.

2 Human-Robot-Game Architecture

The design of the Human-Robot-Game architecture involves a multidisciplinary team of researchers and students from the areas of computer science, electronic, audiovisual production, graphic design, psychology, and education. The goal is to achieve the intervention of HRI and HCI for pilot testing of a proposed Human-Robot-Game (HRG) architecture platform designed for educational purposes. This HRG platform using as a novel prototype of a SAR system linked to serious game apps, adapted for inclusive education, can contributes to the development of social and cognitive skills for ASD children through imitation using the senses of sight, touch, and hearing.

In order to have a modular and scalable hardware and software for the Loly 1.0 robotic platform, the system has been designed around 3 main parts: the robot, the educational game and the cloud services (as shown in Fig. 1).

Fig. 1. General diagram of the Loly 1.0 Educational Robotic Platform Architecture

2.1 The Robot

The parameters that characterize a social robot are form, function, and context. Each robot is given an aesthetic shape depending on its function. Besides, each robot has different types of behavior, that is, variable functions. Finally, the social robot with its aesthetic form and its functions is found within various contexts, and it can also be assigned a character archetype and specific aesthetic design according to a wide range of types, each charged with satisfying different needs.

The main function of the head and torso designed as a robotic bust in this research is to interact with patients with ASD and to keep them focused on a single activity. In turn, it captures game data and real-time data to a dashboard. Expecting to give more expressiveness to the robot [16], an 8-inch LCD screen is used to display main facial expressions: happiness, sadness, anger, and enthusiasm. For verbal interaction, the robot uses a loudspeaker to emit previously established lines of dialogue obtained from the production of the game. The robotic head will produce pitching movements using servo motors controlled by a microcontroller.

For the adaptations of the games in functionality with the robot design, all the required components of programming and real-time linking previously used in apps programmed with Adobe Animate were considered. The file format for data transmission to the dashboard uses JSON records. The communication of the app with the robot uses Java for Android systems. This application communicates via socket directly to the NodeJS Server that receives the information to proceed through serial communication on the movement, audio, and gestures of the robot.

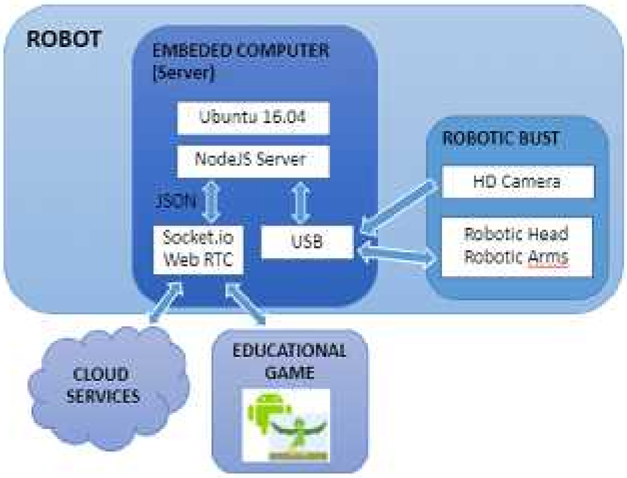

Fig. 2. Diagram of Hardware/Software Robot Architecture

As part of the design, it was implemented a real-time recording and transmission system of the interactive sessions. To accomplish this purpose, modularizing the mobile application with the robot and with the help of a camera installed on the robot were executed.

Communication is established between the mobile application and the robot so that each event produces the development of action in the robot that attracts the child's attention. For this purpose, adaptations are made in the game script to include interaction with the robot. Motor movements, audio, and video playback are included, transmitting usage data in real-time to a dashboard for operator management.

Fig. 3. Modularization of the robot-game-operator application

Aesthetic and Mechanical Design Aspects. As part of the game-robot implementation, the app used requires some design changes and adaptations in programing. For this purpose, as part of the design and production, to present a robot bust with a child-friendly image, it was decided to incorporate one of the main characters of the MIDI – AM project. The archetype of a friendly mealy parrot originally from the tropical forests of Ecuador named LOLY, who guides the use of the games and stories in this series, was then implemented. For the integration of the character's Loly in the app game, called Anibopi, with robotic accompaniment, the new version requires several adaptations as follows: design and illustration of the physical aspects of the character based on the characteristics and symptoms of the ASD children and specific physical characteristics of the mealy-ridden parrot. Subsequently, the physical structures and adaptations of the Loly character were made to the robot's schematic and mechanical structure, considering the anatomical limitations of the structure [17].

Fig. 4. Graphic representation and dimensions of robotic bust Loly1

The robotic head and bust design were performed in a 3D mechanical modeling program. To be built through 3D printing on most of its mechanical components to achieve head, beak, and wing movement. Finally, all the mechanical, electronic and control components are integrated to carry out the relevant tests.

Fig. 5. Loly construction and assembly

2.2 The Educational Games

For the adaptations of the games in functionality with the robot design, all the required components of programming and real-time linking previously used in apps programmed with Adobe Animate were considered. The file format for data transmission to the dashboard uses JSON records. The dashboard is developed in JavaScript, using the SailsJS framework. The database is implemented in PostgreSQL [15]. The communication of the app with the robot uses Java for Android systems. This application communicates via socket directly to the NodeJS server that receives the information to proceed through serial communication on the movement, audio, and gestures of the robot.

The game component chosen is a specific MIDI-AM game for inclusive education redesigned to be used with the robot prototype for testing purposes. The selected games, named Anibopi, helps the learning process of the Living and Non-Living Beings created mainly for children with high and medium performance ASD. These educational game take bases on active learning methods, considered as serious games. The apk of

Anibopi Rb beta version can be upload for free from AppStore or from the MIDI[1] Website to be used for learning and feedback purposes. Anibopi as one of the MIDI-AM series games is monitored through a dashboard for gameplay evaluation, and other usage metrics [9], [15].

2.3 The Cloud Services

The cloud services that will be carried out on the robotic platform, as shown in Fig. 2, are the management of the information generated both in the educational game and in the robot through a dashboard, as well as monitoring and intervention of a specialist, such as a psychologist or an educator, as an operator.

Dashboard Service. Solorzano, Carrera [15] describe that the web architecture dashboard (Midiapi) is taking as reference the one used in the web application TeachTown. For the backend Node JavaScript programming language is used with Sails.js framework and for the frontend is used Angular. PostgreSQL is the database platform, and the file format for data transmission for the games is a JSON. The Midiapi dashboard shows detailed results with a statistical system, but only for its own game. However, the Midiapi modular division architecture seeks to be adapted to other educational gaming systems (Fig. 6).

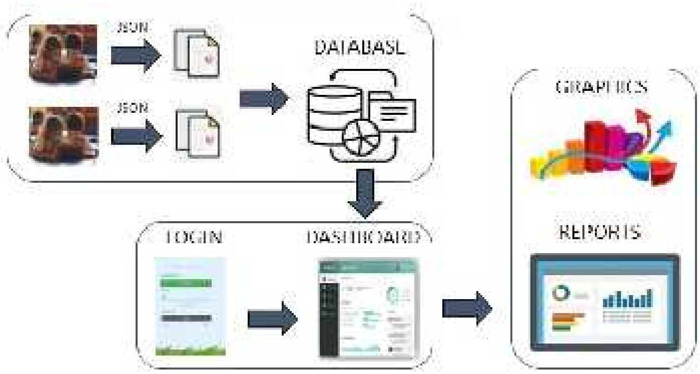

Fig. 6. Midiapi architecture. Illustration base on [15]

Operator Service. As shown in Fig. 3, the design of the architecture includes the participation of an operator. The operator must be a specialist trained to carry out a therapeutic intervention, such as a psychologist. The specialist, who can be connected locally or remotely, can carry out a platform monitoring operation as well as control parameters of both the robot and the educational games that improve the HRG interaction. Expecting to have both video, audio and real-time data connectivity, the design includes the use of a web-based platform called WebRTC.

[1] http://midi.espol.edu.ec/productos

3 Human-Robot-Game Architecture Testing

In order to carry out a first evaluation of the Loly 1.0 architecture, this section presents both the development of technical tests related to the response times of several components, as well as several proofs of concept of human-robot interaction in real environments. Since the Loly 1.0 robotic platform is under development, these first tests only consider the integration of the Robot with the Educational Game.

3.1 Technical Tests

Communication tests with the robot, as well as the server response with the different robot devices, were carried out within the technical tests. The response times are measured since a signal is emitted from the mobile application when executing a button press event through the HTTP protocol through the X-Response-Time tool and the server response, receiving it. Also, the execution of audios and gestures of the robot from the server (see Table 1).

Table 1. Execution and response of times of the different servos.

Event	Http rsponse VS NodeJS server(sec)	Robot response VS server (sec)	Total (sec)
Script 1	0.95	0.36	1.31
Script 2	0.92	0.37	1.32
Script 3	0.80	0. 50	1.30
Script 4	0.90	0.45	1.35

The server implemented with NodeJS technology communicates directly with the different components of the robot, and that includes the servos for movement, the display used for gesticulation, and the speakers that reproduce the audio. The response of the servos used in the four developed scripts is detailed below, which are executed depending on the different interactions or events according to the development of the story (see an example of one of the four scripts, Table 2)

Table 2. Execution and response of times of the different servos. Script 1

Servos	Head	To the left	To the right	Beak	Time	% Execution
Pitch	X				0.2s	33
Yaw	X				0.3s	36
Roll	X				0.3s	42
Wing left		X			0.3s	40
Wing right					--	0
Beak				X	0.3s	72

3.2 Proofs of concept

For testing the proposed HRG architecture platform of Loly 1.0, designed for educational purposes, technical and conceptual research tools for data analysis an experimental evaluation are applying from pragmatic point of view of researchers focusing on solving the problem instead of specific research [18].

First Proof of Concept. The first proof of concept consisted of two HRG interaction sessions with Loly 1.0, one with a five-year-old regular boy and the second session with two girls with high and medium-performance ASD of nine years and five years, respectively (as shown in Fig. 7).

In the first session, we verified that the child mastered the application efficiently, attending to each of the instructions given by the same application, and performing each of the games. This game includes the teachings about plants, animals, rocks, and mountains, showing great skill in the execution and understanding of the game. Regarding physical interaction with the established elements, we obtain two different outcomes. From the session with regular children, they showed more affinity paying attention to the app rather than to the Loly robot. Besides, this was confirmed by asking the children, at the end of the session, what they liked the most? The answer to this question was "the tablet with the game" At the end of the session, the children were asked what they learn using the robot and the game? Then, they were asked to explain about living beings and non-living beings, which fulfills one of the objectives that are the educational play factor present in the game.

Fig. 7. Children playing with Loly

Second Proof of Concept. In this proof of concept, with an ASD children, it was observed, for example, that a nine-year-old girl mastered the application efficiently. She attended the instructions of the game and interacted with each of the sections and levels of the game. Also, she showed good mastery in the topics exposed, due to the general knowledge that the girl already had in understanding each of the topics. Referring to the physical interaction, the girl showed the same degree of affinity for both the mobile application (using a tablet) and the Loly's robot with a highly attraction to the Loly's robot gaze. In the session with the second five-year-old girl, we observed that she partially dominated the application with the support of her parents, with a great attraction to the actions of the robot, her eyes, voice, and gestures, as shown in Fig. 8. This attraction, together with pedagogical and psychological interpretations, gives a preliminary indication that for children with the autism condition, they offer a higher degree of attention to the physical interactions with elements present in the environment (movement, gestures, audio), in this case, on the robot and the Tablet.

Fig. 8. Girl playing with Robot and the App (Courtesy of [2]FEDEA’s President).

Third proof of concept. A work with 20 children between four and six years old from a primary school in Guayaquil city was carried out. It is worth mentioning that in the group, there were two children with Asperger syndrome. The child-robot interaction is recorded by a camera built into the top front of the robot's face. Using computer vision techniques allow knowing the moment when the child pays attention to the robot, that is, the moment he looks at the robot. The tests for the study involve three stages: pre-test, experiment, and post-test.

In the pre-test stage, the possible affinity of children with social robots is observed. The children are asked to select a card they like from among two possible ones expecting to identify their affinity with the robot. The tester shows the children four different cards, which contain a cartoon image of Loly's character, two cards with children's tv series cartoon characters, and another with Loly's social robot picture. for the test, we assume that those children who select the image of the robot were able to identify empathy with the Loly robot. While those who select the cards with other characters we assumed not to.

[2] FEDEA: Federación Ecuatoriana de Espectro Autista - Ecuadorian Autism Spectrum Federation

In the child-robot interaction experiment, the child followed Loly's instructions about what images to watch and drag inside the built-in Tablet. The moments when Loly spoke to the child, to give him the instructions, were the ones to determine if Loly’s appearance likes them by observing their facial expressions. Besides, we seek to identify for how long the child looked at the robot or the app on Tablet, expecting to determine the focus of their attention while they are playing.

In Fig. 9, we can see the times that the children looked at the Loly robot during the interaction with the Tablet, obtaining a range between 3 and 7 times with their smiling gaze towards the robot, which indicates a high degree of attraction of the children with Loly.

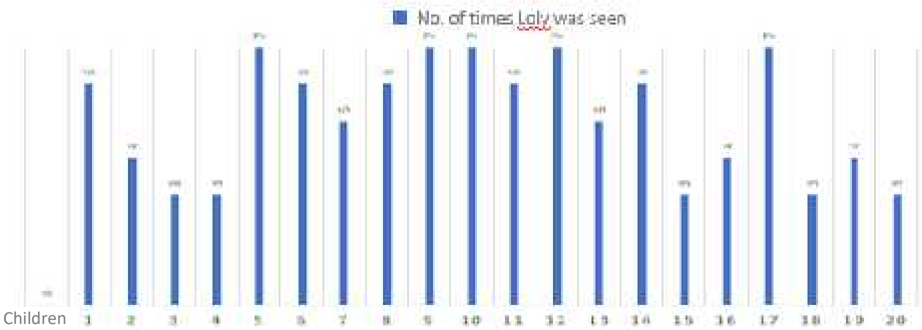

Fig. 9. Frequency of times the child watches the robot

The results of the post-test can be seen in Fig. 10, which indicates that 80% of children chose a card that represents Loly, thus corroborating the results shown in Figure 14. For analyzing results, it was not possible to use only computer vision techniques. It was also necessary to analyze part of the videos manually. This happens because the quality of the camera located frontally in the robot was deficient, and in some cases, the height of the children did not allow them to capture the entire angle of vision. To sum up, the children mostly had a favorable reaction towards the robot, observing their enthusiasm and affinity for the game and the robot at the same time.

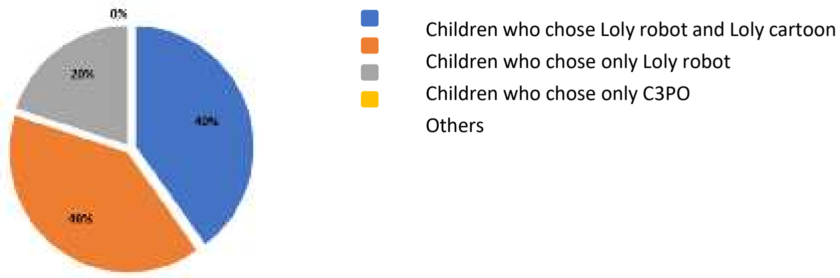

Fig. 10. Preference graph in character selection

In the case of children with Asperger's Syndrome through a social agent, which in this case is the robot, it was found they better retained the information that is being taught. This result is evident in the speed in which they carried out the interactive games that the application offered with a high level of success when playing the levels of the games of the app.

4 Lessons Learned

The lessons learned in the testing process helps to improve a proposed HRG architecture design in terms of hardware/software integration and connectivity, expecting to gather the attention of children with ASD helping them to use a game for succeeding in their teaching-learning process.

The design of engaging and personalized Human-Robot-Interaction (HRI) and Human-Computer-Interaction (HCI) is relevant for inclusive education proposing in this study a combination as Human-Robot-Game interaction explained as HRG.

In general, the testing outcomes helped to accomplish several tasks as follows: evaluate the overall performance platform and a new HRG architecture proposed; the accuracy of Platform of the SAR prototype (Loly 1.0) as the main component of the proposed HRG architecture; connectivity offline/online efficiency, accuracy to link the games between the interaction periods, aesthetic and mechanical issue with the Loly 1.0 prototype, the need of contingency plan or guiding instruction for technical support and pedagogy interventions. Furthermore, another stage of testing event is required to analyze data from the dashboard to evaluate behavioral use, playability and another adoption factors and technical matters such as online/offline, synchronic/asynchrony communications, security, and confidentiality of the entire platform.

On the other hand, focusing the lesson learned based on a first experience in the proof of concept on regards of testing the platform with children with ASD we realized a few matters that should be taken into consideration such as: in some way the child with ASD must be prepared with the human-robot interaction by introducing the robotic character in order to reduce the child's stress or anxiety and plan in advance the customized physical spaces to apply testing individually or to a focus group.

5 Conclusion and Future Work

This research seeks to promote the development, learning process, and social interaction of children with ASD syndrome. We identify many studies focused on helping to improve social skills in these children, but without much success so far. However, based on studies, these children tend to be motivated with the use of technological resources. We propose the design and implementation of a robotic platform with educational games to test the motivation of social interactions and learning in ASD children

The development of the platform and the prototype of a social robot linked to the creation of digital games apps that capture data and present results. With the developed platform, it is possible to make known and interpret information about the usability of these games. The bust of a social robot was built together with an application used in parallel with the robot, which yielded promising acceptance results for children with ASD. Despite not having conclusive results on acceptance, during the different experimentations, it was observed that, in the cases of ASD children, they respond positively to the interaction with the robot at a higher level than regular children, that is, they observe with more exceptional care and enthusiasm both Loly's face and the app.

In the same way, as a post-test through the selection of graphic cards, the positive effect on the degree of acceptance of the Loly robot in conjunction with the educational game could be corroborated.

As future work, this research does not only seek to record the robot-App gameplay results of regular children or children with ASD. It is expected to achieve a more detailed interpretation of how a child uses these educational apps, and the feedback that can be given to teachers, parents, and the developers of educational video games or digital games that interact with other human-machine apps. Technical improvements in the development of the robotic platform, the linked games, and metrics to evaluate the effectiveness of use factors were expected. Based on these premises, it is hoped to continue this research to complete the expected results.

The success of using future social robots as a type of innovative interactive toy to support inclusive education can contribute to evaluating ASD children's learning. Also, it is important to continue venturing into projects that seek to measure the level of children's acceptance, expecting to identify how much they can learn from a ludic game linked to the use of a social-robot interaction, instead of using regular teaching methods. Therefore, further studies for the evaluation of Children-Robot-Game interaction using the designed platform architecture need to be completed.

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