IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 7 Issue 11, November 2020
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

Interaction between children of the autism spectrum and a humanoid robot modulated by levels of consciousness

M. Luz PALACIOS-VILLAVICENCIO[1,2], Ana Lilia LAUREANO-CRUCES[1,3], José Anibal ARIAS-AGUILAR[4] , Roberto FALCÓN-BRETADO[4]

[1] Posgrado de Diseño y Visualización de la Información – Universidad Autonoma Metropolitana -Azcapotzalco
[2]Instituto de Diseño – Universidad Tecnológica de la Mixteca – Oaxaca
[3]Departamento de Sistemas Universidad Autónoma Metropolitana – Azcapotzalco
[4]División de Estudios de Posgrado – Universidad Tecnológica de la Mixteca – Oaxaca
luzpavi, arias, arc.f{@mixteco.utm.mx}, clc@azc.uam.mx

Abstract

The lack of social and emotional reciprocity and the difficulty to implement executive functions (EF) are problems associated with Autism Spectrum Disorder. It has been described that this, together with the difficulty to develop self-awareness, are factors that affect the development of flexibility of thought and in the hierarchization of tasks to think and act efficiently. This article presents a proposal to identify five levels of consciousness in children with Autism Spectrum Disorder associated with levels of cognitive interaction with a humanoid robot. The user-centered design methodology was implemented. The results show that the use of robot expressions associated with a children's level of consciousness can help to program interactions with greater possibilities of communicational interaction.

Keywords: *Autism Spectrum Disorder, Consciousness, Children, User-Centered Design, Human-computer interaction.*

1. Introduction

In the last ten years, an increase in the prevalence of ASD has been detected [1] - [4], and interest in monitoring its incidence rates has increased [5] - [7]. The rise in the numbers [4], [5] has prompted research that favors, on the one hand, the explanation of the disorder [8] and, on the other, the identification of strategies or alternatives to assist for the affected population [9], [10]. Such is the case of the use of humanoid robots that have been used as auxiliary for the socialization of children with ASD [11] - [14].

This article starts with one of the problems associated with autistic disorder that affects the development of cognitive skills efficiently [15], [16]. A proposal is presented to identify five levels of consciousness to implement cognitive interactions between children with ASD and a humanoid robot.

The article is divided into four sections: the *second* describes the theoretical elements: cognitive abilities, autism spectrum disorder, fundamentals of perceptual sensory processing; understood as the basis of the cognitive system and represented by the five levels of consciousness proposed by Igor Aleksander [17], [18] and their relationship with ASD. In the *third*, the methodology is presented. In the fourth, the results and the application proposal for the interactions are integrated. Finally, the *conclusions* are presented.

2. Theoretical elements

2.1 Cognitive skills and autism spectrum disorder (ASD)

The Diagnostic and Statistical Manual of Mental Disorders 5 (DSM-5), considers five criteria for the diagnosis of Autism Spectrum Disorder: a) deficiencies in communication and social interaction, b) presence of restrictive and repetitive patterns of behavior, interests or activities, c) symptoms appear in the early stages of development or when there is a social demand that exceeds their limited capacities, d) clinically significant deterioration in social, occupational or other areas occurs as consequences of symptoms, and e) the disturbances are not better explained by intellectual disability or global developmental delay [19].

According to data from the world health organization [20], ASD is a condition that occurs in one of every 160 inhabitants in the world. The majority of affected children are male in a ratio of 1: 5 to female [3].

It has been described that when the degree of involvement of the disorder is high, there are problems associated with the lack of adaptation of the people who suffer from it, mainly in social interaction and communication. Alcantud Marin [4] comments that it is possible that diagnostic symptoms may be influenced by social and cultural norms. Therefore, also based on that social and cultural influence, there are behaviors typical of ASD that are masked because they are not considered limiting or being so obvious.

Cognitive skills comprise the organization of complex mental activities involved to achieve a goal [15], [21] - [23]. Papazian [24, p. 45] considers them as the result of the mental processes through which internal problems related to the mental representation of the affective, social, communication and motivational and external ones, centered on the direct relationship of the person with their environment.

The approach to cognitive skills in people with ASD is complicated by the lack of skills they show to interpret the social keys that are shared in relationships between people in a spontaneous way. Consciousness and the degree of self-recognition with respect to the environment and others actively participates in this process.

The behavior of people with ASD is related to the difficulty they have in understanding and adjudicating mental states to others and to themselves and has been described as the theory of mind [25], associated with the level of consciousness [26] - [29] and the comprehension problems that people with this disorder experience [30], [31]. Major headings are to be column centered in a bold font without underline. They need be numbered. "2. Headings and Footnotes" at the top of this paragraph is a major heading.

2.2 Basis of perceptual sensory processing

It has been described that some mental abilities "could depend to a largely on the gradual development of language, the speed of information processing and the capacity for attention and memory" in [32, p. 208].

Sensory processing is the basis on which the human cognitive system is constructed. It is carried out in two directions: 1) sensory and then cognitive activation (bottom-up), or 2) cognitive activation and then sensory activation (top down) [33].

Both perception and attention are altered in people with ASD. In this research, the two processes are considered as part of the elements that have to be considered to facilitate contact and communication with people with ASD.

Warrier and Baron-Cohen [34] have documented the difficulty that people with ASD have in imagining and differentiating their own thoughts and emotions from what other people think and feel, placing them in situations of poor cognitive empathy; Baron-Cohen [35] mention that this response is accompanied by up to 90% of perceptual alterations with implications in all their sensory systems. Therefore, the characteristics of these objects are important to ensure that they will be within perceptual range, trying to reduce the "noise" that interferes with the monitoring of cognitive abilities.

The general characteristics of the objects were considered from the observations reported [35, pp. 672–673] as described in Table 1.

Table 1. Characteristics of the objects that influence the perception of people with ASD

Sensory modality	Aspects perceived or altered by people with ASD
Visual	Three levels of observation patterns have been identified: 1st. They tend to focus on details such as color, contrast and orientation. 2nd. Then they perceive the size, density or complexity of the contour. 3rd. They focus on characteristics of semantic content such as text or face identification.
Tactile perception	Alterations in the temporal characteristics of sensory processing have been identified.
Auditory perception	Delays in auditory response latencies have been detected, especially in complex social stimuli such as speech sounds, which could have higher-order implications for communication.
Multisensory integration	They present problems in relation to the time to discern between one stimulus and another, between synchronous and asynchronous events. This has been detected especially when they have been explored with audiovisual mechanisms, it is considered that it is due to the integration of stimuli from various sensory pathways.
Temporal processing	They have reflected problems associated with various sensory modalities. It has particularly been observed in delayed evoked responses in the auditory domain and in the integration of multiple local stimuli.

Note. The table presents data from [35] related to sensory modality and its description.

Both perception and attention facilitate awareness of surrounding things, but it is attention that allows us to capture a part of what is happening, even in a limited way [36]. As part of the cognitive process, its selection mechanism makes it easier for the brain to filter relevant information, hold it and manipulate it to give it the use it requires at the right time [37]. Attention manages to cross the barrier of conscious access described in [38], giving a guideline for meaningful things and with sufficient force of attraction to activate consciousness.

Attention and self-awareness or self-analysis are the essential ingredients for putting cognitive skills into practice. Through these, the person values their subjective experiences to use them in solving problems and guiding decision-making in the present [15].

2.3 Consciousness and ASD

The level of awareness that one has of oneself and of others influences the self-regulation of behavior, emotions and cognition in response to internal and external stimuli [41]. Social cognitive development, which depends on the maturation of the neural system, influences social imitation, their self-referential cognition, and their ability to empathize with others [17].

One of the keys to awareness in people, part of the self-concept or self-image that they have of themselves. This is acquired and molded from interaction with the environment and particularly with other people [18]. This is why, for people with ASD, having a self-image reference is delayed compared to regular children. Although self-awareness is not easily defined for people with ASD, this is not a parameter that can be evaluated based on the diagnostic criteria of the DSM-5. However, some theories such as the theory of mind focus on this aspect and allow us to explore the degree of consciousness that one has in the state of ASD.

From the perspective of artificial consciousness, Igor Aleksander [17], [18] focuses and analyzes the ordinary functioning of the human brain to develop a model of artificial consciousness. The analogy makes it easier to specify each level of consciousness that is necessary to identify the level of rapport that a person or an agent can have during an interaction.

In this work, it is retaken the application made by Laureano-Cruces and his collaborators [42], [43], [44] of the theoretical proposal of artificial consciousness formulated by [18]. The particularity of the adaptation presented in this research is that the theoretical basis serves to explain a series of practical interventions that can be done with children with ASD in tasks that involve the use of their cognitive abilities. That is, the theory is not necessarily used to develop artificial consciousness, but to explain the levels of development that children would achieve while interacting.

3. Methodology

Humanoid robots have been identified as attractive and can act as communication intermediaries with children with ASD, which makes them excellent mediator candidates to explore the keys to communicational exchange, the signs that activate their meaning processes and the degree of consciousness they have of themselves and of the other.

The techniques and methodologies of human computer interaction HCI have focused on designing more usable computer systems [45, p. 54]. Although they have been predominantly implemented in digital interactive experiences [46], their use to assess human-robot interaction (HRI) has offered advantages [47] - [49] in children with ASD. The research was developed under the approach of user-centered design in the extended version (Figure 1, UCDe) proposed by Richard Harper et al. [45].

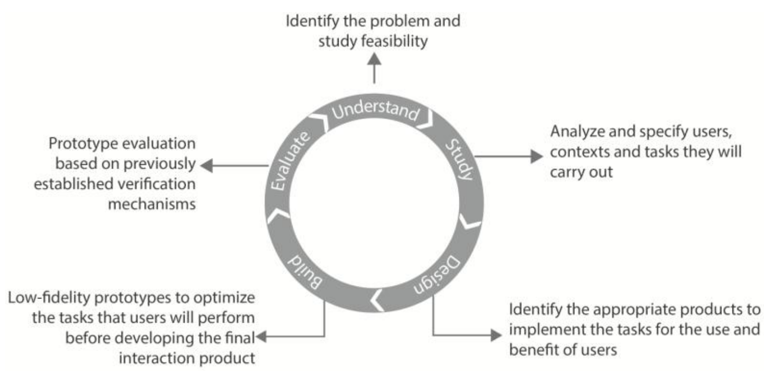


Figure 1. User-Centered Design Methodology, extended version. Source: [45] with own description.

3.1 Procedure

3.1.1 Understand.

The scope that could be had in the study was detected from three areas of knowledge: special education, design, robotics and artificial intelligence (Table 2). During this phase, those responsible were also contacted to identify the general characteristics of the children.

Table 2. Participants in the conceptualization and execution of the study

	Intervention and tasks performed
Special education	Evaluate the educational feasibility of cognitive skills exercises
Design	Conceptualization and design of tasks to assess cognitive abilities
Robotics	Python interface design and programming of robotic execution to direct robot-child interaction
Artificial intelligence	Proposal for analysis and application of axioms of consciousness from the perspective of Igor Aleksander

Source: own elaboration

3.1.2 Study.

Specialists in the areas mentioned in the previous process were consulted. The participation of each area was delimited according to the intervention and tasks that they had to develop for the implementation of the research. The users, the tasks and the context of use were defined.

- *Context.* A contextual study was developed to obtain directly the information of the users and participants in their context of use; an autism clinic. In the case of the information from the specialists, the development was in the robotics laboratory facilities where the robot programming was carried out. In Table 2, the contributions by area are described.
- *Users.* Child-human interaction exercises were planned to put into practice the adequacy of the cognitive skills associated with a level of consciousness, they were evaluated by specialists in special education, the parameters described in Table 2 were considered.
- *Tasks.* Through the analysis of cognitive skills exercises designed for children under parameters of educational feasibility, design and robotics. The five tasks related to the five levels of consciousness described by Igor Aleksander [40], [41] were proposed: 1) identify own presence, 2) have an act of imagination, 3) activate attention, 4) activate volition, and 5) activate the emotion. All of them associated with a perceptual level described in Table 1.

3.1.3 Design.

From the results of the first two steps of the methodology: 1) the tasks that would be implemented to evaluate the levels of consciousness in interaction were defined, 2) the feasibility of the study was explored, and 3) the criteria were established to identify the elements of significance of the participants. The pathways that could be implemented during the interaction between the children and the humanoid robot were conceptualized and designed.

3.1.4 Build.

It focused on the development of the interaction interfaces between the humanoid robot and children.

3.1.5 Evaluate.

The last process of the methodology was proposed to be applied to the final interaction considering the elements of expression of the robot and communication to activate the tasks proposed for children.

4. Results

4.1 Diagnostic exploration of study feasibility

It focused on identifying the differences in the type of interaction that three groups of children established with the robot: a) 7 children with ASD, b) 11 children with special educational needs (SEN), and 3) 17 neurotypical children. A differentiation was not made by age, gender, or by degree or type of disability because the objective was to explore roughly whether or not there was an intention to interact. However, it should be mentioned that, in the group of children with ASD, only one girl was registered.

Table 3 shows: the number of cases considered (N) and the behavioral parameters that were explored. 1) positive interaction reaction (R +), 2) negative interaction reaction (R-). In these first two parameters, it was considered whether they responded to the presence with the robot (positive) or if they did not respond (negative). Parameter three was imitative behavior (IB) in which the children were asked to do the same as the robot did. Parameter four consisted in registering whether or not the children attended the robot's actions (A). And finally, in parameter four, the willingness to interact with adults while doing the evaluation was considered. In this first interactive evaluation, the only objective was to be certain of the feasibility of the study of children with ASD.

Table 3. General exploration of child-robot interaction

Group	**N**	**Comparison parameters**				
		R+	R-	CI	A	IS
With ASD	7	5	2	2	7	1
Neurotypical	11	11	0	11	11	11
Other SEN	17	16	1	15	15	17

Note: general response of the child-robot interaction. Number of participants (N), positive reaction to interaction with the robot (R +), negative reaction to interaction with the robot (R-), imitative behavior (IB), attention (A) and reaction in spontaneous social interaction with adults (IS). The data on the number of children who did present a response in the corresponding behaviors are shown.

In Figure 2, the behavioral tendency of the different groups is observed according to the evaluated behaviors. The trend of the neurotypical group and the group with SEN remain very similar, which means that for both groups the interaction was adequately fulfilled in the four parameters evaluated. However, in children with ASD, a high percentage of response was only obtained in the parameter of positive reaction, but it was not maintained in the other parameters.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 7 Issue 11, November 2020
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

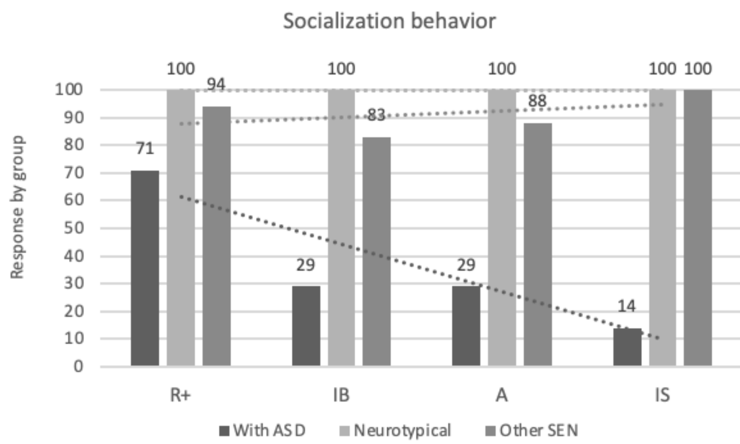


Figure 2. The dotted line shows the trend of the positive reaction of the robot-child interaction directed towards the reaction in spontaneous social interaction with adultss; It is based on Table 1, which shows the response percentages by group.

4.2 Diagnostic characterization of the participants

Regarding the procedural definition, the diagnostic criteria (Table 2) that will be considered for the profile of the children who will participate in the study were defined. These criteria were obtained from the Diagnostic Manual of Mental Disorders in version 5 [1].

4.3 Identification of elements of significance for the study group

The second procedural definition begins with the identification of the elements that are significant for children with ASD. These elements of significance will be considered in the implementation of the cognitive-affective interaction scenarios of the robot and the children.

Table 4. Severity levels of ASD

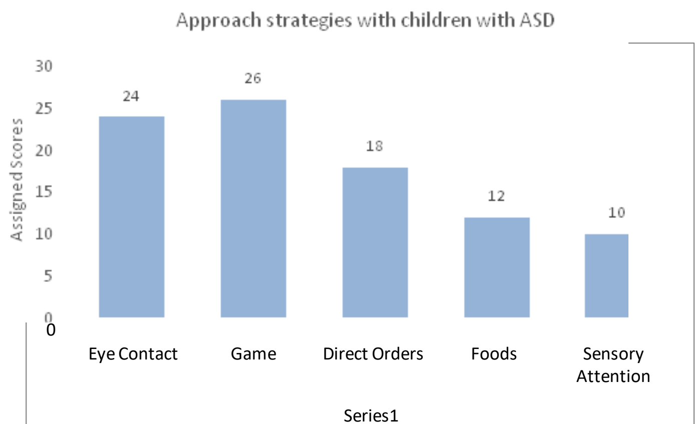
Severity level	Social comunication	Restricted and repetitive behaviors
Level 3 Severe/Requiring very substantial support	Minimal response to socialize with other people	Inflexibility of behavior in all areas, and to change the focus of attention
Level 2 Moderate/Requiring substantial support	Limited initiation of social interaction	Inflexibility of behavior in some contexts, and to change the focus of attention
Level 1 Mild/Requiring support	Little interest in maintaining social interaction	Inflexibility of behavior. Difficulty alternating activities and organizational problems

Note: description of ASD severity levels based on DSM-5 diagnostic criteria.

4.4 Hierarchy of cognitive skills from the perspective of special education

Special education teachers were asked to describe what outreach strategies they follow to interact with children with ASD. Later they were asked to assign from 1 to 6 points (one being the least important) to these strategies. The strategy that had the highest score was play with 26 points, eye contact with 24 points, and direct orders with 18 points (Figure 3). Food strategy was considered unsuitable for be used in interactions.

Table 5. Robot expressions associated with interactive behavior



This data was used to determine how interactions with the children could be initiated during the assessment. Subsequently, the robot expressions that could be used to reinforce the interventions with the children were characterized, considering these strategies. In Table 5, an example of expressions of the robot which could be considered to be implemented during interactions occurs.

Strategies	Expressions		
Eye contact	 But	 Happy	 Hello
Game	 Interested	 Happy	 Mocker
Direct orders	 ComeOn	 Far	 Hey
Sensory attention	 Hey	 LightShine	 Salute

Figure 3. Approach strategies recommended by specialists in special education. Source: own elaboration.

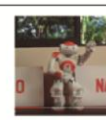
4.5 Application of levels of consciousness from the perspective of Igor Aleksander

Igor Aleksander [17], [18] proposes a model to define and apply consciousness in artificial systems. However, its theoretical basis focuses on human reactions. His proposal is defined by him as an "<< axiomatic / introspective method >>, which breaks down the concept of being conscious into elements that have reasonably clear transitions in neural architectures" [17, p. 22]**.**

In the system it develops [17], five elements of consciousness are broken down translated as neural mechanisms that indicate: "presence, imagination, attention, volition and emotion" [17, p. 25], each of them gives a guide to the axioms of their proposal. For a complete reference of the axioms see [17], [18], [50]. For a review of the application of the axioms, review the work of Laureano-Cruces and his collaborators [42], [43], [44]. The use that is given to the axioms in this work is referential and its purpose is to explain the behavior of people with ASD from a practical model.

The elements of consciousness are essential to identify whether internal or external information is present to the individual himself. However, realizing that there is a world inside or outside of oneself is only part of regulating the behavior of a person or an agent. This, as well as consciousness and cognitive abilities, form a hierarchical structure that is activated in its most complex form as the levels of attention and alertness of a person increase. In Table 6, the axioms, the definition of each one, and the interaction exercises in which each one was applied are presented.

Table 6. Axioms of consciousness related to planning interaction with the robot

Axiom	Definition	Using robot expressions to interaction				
		Eye contact	Game	Direct orders	Sensory attention	Corporal expression of the robot interacting
1 I feel like I'm focused on an outside world	**Observation of an external environment and of oneself in relation to the external environment.** The "outside world" is phenomenally represented, with its own independent existence. The world is internalized through the recognition of oneself and the environment.				Visual perception (an image is presented)	
2. I can not only remember past experience, but also fictitious imagination	**Observation of hypothetical or imaginative thoughts** Imagine and evoke perceptions and past information, as a reference of what is lived and experienced at each moment. There is a sensory integration that perceives, understands and integrates the world	Visual perception (identify-cation of shapes)			Auditory perception (sound)	
3. I am only aware of what I attend	**Observation of internal thoughts.** Focus on the ability to keep your attention on what needs to be done according to the context				Temporal processing (more than two stimuli at the same time)	
4. I can select what I want and I can act to get it	**Time observation: present, past and potential future** It focuses on the ability to plan from an introspective thought that leads to the execution of the behavior according to a previously established plan	Multisensory integration				
5. I can evaluate the results of planning different actions according to previous experience	**Reflective observation: seeing itselfself** They are cognitive manifestations that evoke the experiences		Temporary actions pro-cessing			

Note. Definition and application guide of axioms related to consciousness with exercises of cognitive skills based on [35].

4.6 Bases for the design of the robotic planning interface

From the integration of the axioms proposed by Igor Aleksander [17], [18] the parameters can be established to define the design of the interface to control the movements of the robot. Next, the elements that will serve as verification mechanisms for each axiom associated with the expected response during child-robot interactions are mentioned. In Figure 4, an example of the interface used to control an eye color change task is presented.

- *Axiom 1*
  Checking mechanism. Let the user change their alert status.
- *Axiom 2*
  Checking mechanism. That the user performs the basic activities requested by the robot verbally or by body language.
- Axiom 3
  Checking mechanism. That the user has a recognition of the stimuli that are presented to him.
- *Axiom 4*
- Checking mechanism. That the user puts into practice his volitional capacity, involving an internal planning of his actions.
- *Axiom 5*
  Checking mechanism. With the use of exercises that stimulate the activation of the will, it would be expected to activate the emotional mechanisms associated with self-awareness or social awareness.

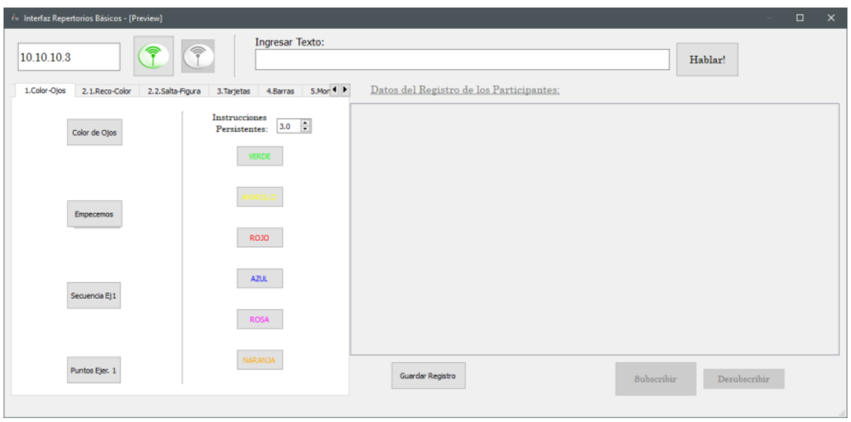


Figure 4. Example of the interface design in PYTHON; applied as robot expression changing eye color.

From the aforementioned proposal, the robot control interfaces based on the axioms could be developed. With this, robotic planning can be developed to implement humanoid robot interactions with children with ASD.

Follow up on children's behavior based on their reactions considering the levels of consciousness proposed by Igor Aleksander [17], [18]; they could serve as a basis for exploring the process, responsiveness and accomplishment that children achieve by following instructions in interacting with a humanoid robot.

5. Conclusions

The results presented in this study are a general analysis of the possibilities of child-robot interaction exploration. As previously mentioned, these tests were carried out in order to validate the feasibility of the complete study in which cognitive interactions with an emphasis on the phenomenon of consciousness will be included.

These results are the basis for the development of subsequent stages of research focused on the design and analysis of cognitive interaction scenarios implementing the five axioms of [17], [18] based on artificial consciousness, taking as an axis the cognitive abilities of the children with ASD.

It is emphasized -that it is necessary to have a prior knowledge of the degree of affectation of the disorder, as well as to identify the objects of greatest significance for children in order to be able to adapt the scenarios of interaction of the robot with them more precisely. Hence, the identification of their symbolic keys will help to establish a better communicational exchange and reduce barriers for reciprocal social interaction between the children and the robot. These keys are in the objects that maintain their repetitive and stereotyped behavior patterns.

Acknowledgments

This work is part of the research project conducted by María de la Luz Palacios-Villavicencio to obtain the degree of PhD. in Diseño y Visualización de la Información at Universidad Autónoma Metropolitana -Azcapotzalco; as well as the divisional project Design of Intelligent Interfaces for Simulating the Behavior of Living or Animate Organisms; information visualization section; from the same University. It was partially developed with the support of the Project: PROMEP DSA / 103.5 / 15/11133 of the Universidad Tecnológica de la Mixteca. And with the support of the doctoral scholarship awarded by the Universidad Autónoma Metropolitana – Azcapotzalco.

References

[1] Baron-Cohen S., "Empatia cero. Nueva teoría de la crueldad", 1era. Edición, Madrid, España: Alianza Editorial, 2012.

[2] Málaga I., Lago R. B., Hedrera-Fernández A., Álvarez-Álvarez N., Oreña-Ansonera V. A., Baeza-Velasco M., “Prevalence of autism spectrum disorders in USA, Europe and Spain: Coincidences and discrepancies”, Medicina, vol. 79, núm. 1, pp. 4–9, 2019.

[3] Christensen D. L., Maenner M., Bilder D., Constantino J., Daniels J., Durkin M., Fitzgerald R., Kurzius M., Spencer M., Pettygrove S., Robinson C., Shenouda J., White T., Zahorodny W., Pazol K., Dietz P.,“Prevalence and Characteristics of Autism Spectrum Disorder Among Children Aged 4 Years - Early Autism and Developmental Disabilities Monitoring Network, Seven Sites, United States, 2010, 2012, and 2014”, Morbidity and mortality weekly report. Surveillance summaries (Washington, D.C. : 2002), vol. 68, núm. 2, pp. 1–19, 2019.

[4] Alcantud-Marín F., Alonso-Esteban Y., Mata-Iturralde S., “Prevalence of autism spectrum disorders: Data review”, Siglo Cero, vol. 47, núm. 4, pp. 7–26, 2016.

[5] Posada-De la Paz M., Ferrari-Arroyo M. J., Touriño E., Boada L., “Investigación epidemiológica en el autismo: una visión integradora”, Revista de Neurología, vol. 40, núm. (Supl 1), pp. S191–S198, 2005.

[6] Chen C. P., Gau S. S. F., Lee C. C., “Toward differential diagnosis of autism spectrum disorder using multimodal behavior descriptors and executive functions”, Computer Speech and Language, vol. 56, pp. 17–35, 2019.

[7] Artigas-P J., Paula I., “El autismo 70 años después de Leo Kanner, Hans Asperger”, Revista de la Asociación Española de Neuropsiquiatría, vol. 32, núm. 115, pp. 567–587, 2012.

[8] Mulas F., Ros-Cervera G., Millá M. G., Etchepareborda M. C., Abad-Mas L., Téllez-de Meneses M., “Modelos de intervención en niños con autismo”, Revista de Neurologia, vol. 50, núm. Supl. 3: S77-S84, 2010.

[9] Huijnen C. A. G. J., Lexis M. A. S., Jansens R., De Witte L. P., “How to Implement Robots in Interventions for Children with Autism? A Co-creation Study Involving People with Autism, Parents and Professionals”, Journal of Autism and Developmental Disorders, vol. 47, núm. 10, pp. 3079–3096, oct. 2017.

[10] Zantinge G., Van-Rijn S., Stockmann L., Swaab H., “Physiological Arousal and Emotion Regulation Strategies in Young Children with Autism Spectrum Disorders”, Journal of Autism and Developmental Disorders, vol. 47, núm. 9, pp. 2648–2657, 2017.
[11] Liu X., Liu C., Zhou X., Zhou X., Jiang A., “Movement imitation underlying coaching platform for children with ASD”, IEEE International Conference on Consumer Electronics-Taiwan, ICCE-TW, pp. 57–58, 2015.
[12] Giullian N., Ricks D., Atherton A., Colton M., Goodrich M., Brinton B., “Detailed requirements for robots in autism therapy”, en Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics, 2010, pp. 2595–2602,
[13] Hamid A. C., Miskam M. A., Yussof H., Shamsuddin S., Hashim H., Ismail L., “Human-robot interaction (HRI) for children with autism to augment communication skills”, Applied Mechanics and Materials, vol. 393, pp. 598–603, 2013.
[14] Yun S. S., Choi J. S., Park S. K., Bong G. Y., Yoo H. J., “Social skills training for children with autism spectrum disorder using a robotic behavioral intervention system”, Autism Research, vol. 10, núm. 7, pp. 1306–1323, jul. 2017.
[15] Tirapu-Ustárroz J., Muñoz-Céspedes M., Pelegrín-Valero C., Albéniz-Ferreras A., “Propuesta de un protocolo para la evaluación de las funciones ejecutivas”, REV NEUROL, vol. 41, núm. 3, pp. 177–186, 2005.
[16] Bertollo J. R., Yerys B. E., “More than IQ: Executive function explains adaptive behavior above and beyond nonverbal IQ in youth with autism and lower IQ”, American Journal on Intellectual and Developmental Disabilities, vol. 124, núm. 3, pp. 191–205, 2019.
[17] Aleksander I., “Designing conscious systems”, Cognitive Computation”, vol. 1, núm. 1, pp. 22–28, 2009.
[18] Aleksander I., “The World in my Mind, My Mind in the World”. Imprint Academic, 2005.
[19] A. American Psychiatric Association, “Manual diagnóstico y estadístico de los trastornos mentales (DSM–5)”. Editorial médica panamericana, España, p. 947, 2014.
[20] O. M. de la salud (OMS), “Autism spectrum disorders”, 2019, Available: https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders.
[21] Bock O., Haeger M., Voelcker-Rehage C., “Structure of executive functions in young and in older persons”, PLoS ONE, vol. 14, núm. 5, pp. 1–20, 2019.
[22] Calle-Sandoval D. A., “Filogenia y desarrollo de funciones ejecutivas/ Phylogeny and executive functions development”, Psicogente, vol. 20, núm. 38, pp. 368–381, 2017.
[23] Tirapu-Ustárroz J., Luna-Lario P., “Neuropsicología de las funciones ejecutivas”, en Manual de neuropsicologia, 2a., J. Tirapu-Ustárroz, M. Ríos-Lago, F. Maestú, Eds. España: Viguera editores, 2011, pp. 220–259.
[24] Papazian O., Alfonso I., Luzondo R. J., “Trastornos de las funciones ejecutivas”, Rev. Neurol, vol. 42 (Supl 3), pp. S45–S50, 2006.
[25] Baron-Cohen S., Leslie A. M., Frith U., “Does the autistic child have a ‘theory of mind?”, Cognition, vol. 21, núm. 1, pp. 37–46, 1985.
[26] Morin A., “Self-recognition, theory-of-mind, and self-awareness: What side are you on?”, Laterality, vol. 16, núm. 3, pp. 367–383, 2011.
[27] Morin A., “Levels of consciousness and self-awareness: A comparison and integration of various neurocognitive views”, Consciousness and Cognition, vol. 15, núm. 2, pp. 358–371, 2006.
[28] Pedreño C., Pousa E., Navarro J. B., Pámias M., Obiols J. E., “Exploring the Components of Advanced Theory of Mind in Autism Spectrum Disorder”, Journal of Autism and Developmental Disorders, vol. 47, núm. 8, pp. 2401–2409, 2017.
[29] Pelligra V., Isoni A., Fadda R., Doneddu G., “Theory of mind, perceived intentions and reciprocal behaviour: Evidence from individuals with Autism Spectrum Disorder”, Journal of Economic Psychology, vol. 49, pp. 95–107, ago. 2015.
[30] Schneider D., Slaughter V. P., Dux P. E., “What do we know about implicit false-belief tracking?”, Psychonomic Bulletin and Review, vol. 22, núm. 1, pp. 1–12, 2014.
[31] Davidson D., Vanegas S. B., Hilvert E., “Proneness to Self-Conscious Emotions in Adults With and Without Autism Traits”, Journal of Autism and Developmental Disorders, vol. 47, núm. 11, pp. 3392–3404, 2017.
[32] Ardila A., "Guía para el diagnóstico neuropsicológico", 2012, Available: http://ineuro.cucba.udg.mx/libros/bv_guia_para_el_diagnostico_neuropsicologico.pdf.
[33] Pastor-Cerezuela G., Fernández-Andrés M. I., Sanz-Cervera P., Marín-Suelves D., “The impact of sensory processing on executive and cognitive functions in children with autism spectrum disorder in the school context”, Research in Developmental Disabilities, vol. 96, núm. November 2019, p. 103540, 2020.
[34] Warrier V., Baron-Cohen S., “Genetic contribution to ‘theory of mind’ in adolescence”, Scientific Reports, vol. 8, núm. 1, pp. 1–9, 2018.

[35] Robertson C. E., Baron-Cohen S., “Sensory perception in autism”, Nature Reviews Neuroscience, vol. 18, núm. 11, pp. 671–684, 2017.

[36] Grondin S., "Psychology of percepcion", 1era. ed., Québec, Canada: Springer Nature Switzerland AG, 2016.

[37] Soprano A. M., "Cómo evaluar la atenciòn y las funciones ejecutivas en niños y adolescentes", 2a. Buenos Aires Argentina: Paidós, 2014.

[38] Dehaene S., "La conciencia en el cerebro. Descifrando el enigma de cómo nuestro cerebro elabora nuestros pensamientos", 1a. Buenos Aires, Argentina: S.XXI editores, 2015.

[39] Henderson H. A., Mundy P. C., “The Integration of Self and Other in the Development of Self-Regulation”, Handbook of Self-Regulatory Processes in Development, núm. 11531, 2015.

[40] Lombardo M. V., Barnes J. L., Wheelwright S. J., Baron-Cohen S., “Self-referential cognition and empathy in austism”, PLoS ONE, vol. 2, núm. 9, 2007.

[41] Huan A. X., Hughes T., Sutton L., Lawrence M., Chen X., Ji Z., Zeleke W., “Understanding the self in individuals with Autism Spectrum Disorders (ASD): A review of literature”, Frontiers in Psychology, vol. 8, núm. AUG, pp. 1–8, 2017.

[42] Laureano-Cruces A. L., Ramírez-Rodríguez J., Mora-Torres M., Sánchez-Guerrero L., "Artificial Self Awareness for Emergent Behavior", In Frontiers in Psychological and Behavioral Science. Vol. 5, Iss. 1, pp. 1-15. ISSN:2309-012X(Print); ISSN:2309-0138(Online). 2016.

[43] Laureano-Cruces A. L., Mora-Torres M., Sánchez-Guerrero L., Ramírez-Rodríguez J., Montiel-Bernal I. I., Allier-Pavia E. B., “Dynamic Interaction through a Reactive Interface in Patients with Dementia, by Means of Cognitive Stimulation”, E-Health Telecommunication Systems and Networks, vol. 04, núm. 04, pp. 57–67, 2015.

[44] Ramírez-Laureano E., Laureano-Cruces A. L., Ledo-Mezquita Y., Flores-Mendoza C., “Conscious interfaces: a shared responsibility”, IJISET - International Journal of Innovative Science, Engineering & Technology, vol. 5, núm. 1, 2018.

[45] Harper R., Rodden T., Rogers Y., Sellen A., "Being Human: Human-Computer Interaction in the year 2020", England: Microsoft Research Ltd., 2008.

[46] Alanwood G., Beare P., "Diseño de experiencias de usuario", 2a. Parramón arts & design, 2015.

[47] Breazeal C., “Social interactions in HRI: The robot view”, IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews, vol. 34, núm. 2, pp. 181–186, 2004.

[48] Dağlarlı E., Dağlarlı S. F., Günel G. Ö., Köse H., “Improving human-robot interaction based on joint attention”, Applied Intelligence, vol. 47, núm. 1, pp. 62–82, 2017.

[49] Jyoti V., Lahiri U., “Human-Computer Interaction based Joint Attention cues: Implications on functional and physiological measures for children with autism spectrum disorder”, Computers in Human Behavior, vol. 104, núm. June 2019, p. 106163, 2020.

[50] Chrisley R., Aleksander I., Bringsjord S., Clowes R., Parthemore J., Stuart S., Torranc S., Ziemk T., “Assessing artificial consciousness: A collective review article”, Journal of Consciousness Studies, vol. 15, núm. 7, pp. 95–110, 2008.

M. Luz PALACIOS-VILLAVICENCIO, is a psychologist, graphic designer and have a master degree in science. Since 2006 she is a full-time professor-researcher, and Director of the Design Institute of the Universidad Tecnológica de la Mixteca. Her lines of research are cognitive processes and design with an inclusive approach. She has led funded projects focused on the design and interaction of children with ASD and interactive, manipulative devices and with the NAO humanoid robot. She created the first sensory stimulation room for disability in Oaxaca and has directed more than 15 support prototypes for functional diversity.

Ana Lilia LAUREANO-CRUCES, obtained a bachelor’s degree in Civil Engineering, a Master’s degree in Computer Sciences, and a Ph.D. degree in Science at UNAM. She has been a full-time professor at Universidad Autónoma Metropolitana - Azcapotzalco since 1987. She was a guest researcher between 1) 1998 and 2000, at the Departamento de Sistemas del Instituto de Automática Industrial del Consejo Superior de Ciencia y Tecnología de Madrid (SPAIN), 2) September 2011-April 2013 at Université d'Avignon et des Pays de Vaucluse (UAPV, FRANCE). Her main areas of interest are: Expert Systems and Intelligent Systems applied to the teaching-learning process, Affective Computing, Cognitive Emotions, Reactive Agents, Pedagogical Agents, Multi-Agent Architectures, Behavioral Analysis, Adaptive Control, Cognitive Engineering, Knowledge Representation, and Artificial Consciousness.

José ANIBAL ARIAS-AGUILAR, studied Communications and Electronics Engineering at IPN, Master's Degree in Computer Systems at UDLA-Puebla, Master's Degree and PhD in Computer Science of Image and Language at Paul Sabatier University (Toulouse, France). He worked for a year as a temporary professor at the Université de Pau et des Pays de l'Adour (Anglet, France). He is currently a professor-researcher at the UTM and teaches courses in master's degrees in Robotics and Interactive Media, as well as doctorates in Electronics and Robotics.

Roberto Falcon BRETADO-GALLEGOS, studied the Bachelor's Degree in Electronic Engineering at the Technological University of the Mixteca. He has taught various courses and workshops on programming for human-robot interaction scenarios. He is an academic technician at the same University.