Proposal of Games for Children and Teenagers with Down Syndrome Applied to a Socially Assistive Robot

Sheila da Luz Schreider
Postgraduate Program in Biotechnology
Federal University of Espirito Santo
Vitoria, Brazil
ORCID: 0000-0003-4603-3492

João Antonio Campos Panceri
Postgraduate Program in Electrical Engineering
Federal University of Espirito Santo
Vitoria, Brazil
ORCID: 0000-0001-7878-2880

Teodiano Freire Bastos-Filho
Postgraduate Program in Electrical Engineering
Postgraduate Program in Biotechnology Federal University of Espirito Santo Vitoria, Brazil
ORCID: 0000-0002-1185-2773

Éberte Valter da Silva Freitas
Postgraduate Program in Electrical Engineering
Federal University of Espirito Santo
Vitoria, Brazil
ORCID: 0000-0001-5774-4017

Andrea Montero-Contreras Department of Biomedical Engineering Universidad Iberoamericana
Ciudad de México, México
ORCID: 0000-0002-9466-4662

Josiany Carlos de Souza
Postgraduate Program in Biotechnology Federal University of Espirito Santo Vitoria, Brazil
ORCID: 0000-0001-6777-0227

Eliete Maria de Oliveira Caldeira
Department of Electrical Engineering Federal University of Espirito Santo Vitoria, Brazil
ORCID: 0000-0002-3742-0952

Abstract—**The recent incorporation of robots in therapies that aim to improve the quality of life of children with some type of disability, physical or intellectual, demonstrates that robotics has assumed a prominent position in contemporary life. Assistive robots have tools that stimulate social, cognitive, and physical skills, showing its ability to promote improvement in these children's behavioral and physical aspects. This work aims to describe a protocol of serious games implemented in a new assistive robot entitled, MARIA T-21 (Mobile Autonomous Robot for Interaction with Autistics and Trisomy 21). This study presents a method for intervention using the robot, which is based on proprioception, postural balance, and gait of children with Down Syndrome (DS), aged between 5 and 15 years, in addition to therapeutic collaboration tools, which provide a playful form of therapy, greater interaction between body and mind, and greater adherence to therapies for these children.**

Keywords — Assistive Robotics, Serious Games, Down Syndrome, Rehabilitation.

I. INTRODUCTION

The recent incorporation of robots in therapies that aim to improve the quality of children's life with some type of disability, physical or intellectual demonstrates that robotics has assumed a prominent position in contemporary life. Assistive robots have tools that stimulate social, cognitive, and physical skills, showing the ability to promote improvement in the behavioral and physical aspects of these children [1].

Many studies highlight the importance of "socially assistive" robotics as a significant tool for interacting with children with Trisomy 21 (T21), stimulating their social, cognitive, and physical skills, and being able to improve the effects of therapies [2].

T21 is the most common genetic disorder related to delayed neuropsychomotor development [3]. This syndrome is associated with hypotonia and may be associated with other pathologies, such as congenital heart disease, hearing, and visual problems, changes in the cervical spine, obesity, thyroid disorders, and premature aging [3, 4].

Hypotonia is a reduction in muscle tonus and, in this condition, there is a delay in the start of muscle contraction, affecting the ligament structures, so that the ligaments are loose, and the joints have a greater degree of range of motion, characterizing joint hypermobility [5].

Hypotonia and joint hypermobility interfere with postural control, proprioception, and influence sensory, motor, and exploration experiences of the environment, which become reduced [6], thereby exercising an influence on the individual's proprioception. This is a term that encompasses the perception of the body itself in the environment, from the movement, positioning of the joints, recognition of body segments, perception of movement and changes in body balance [7, 8].

Since children with T21 have the aforementioned characteristics, it is recommended to conduct therapy sessions, including early stimulation with physiotherapy, which shows evident results at the improvement of neuropsychomotor development and social ability of these children [9].

In this work, a proposal of psychomotor therapy in addition to a method of assessing functional performance are presented, which use an assistive robot for intervention in proprioception, postural balance, and gait of children with Down Syndrome (DS).

In our previous work, a robot (termed New- MARIA) [10] was used to provide the therapist with a set of tools to assist in the therapy of children with Autistic Spectrum Disorder (ASD). This robot used an RGB camera, a thermal camera and touch sensors spread over the surface of its body to interact with the children. In its head, a 10-inch screen displayed emotions, such as joy, disgust, anger, sadness, surprise, and neutrality, and speakers emitted sound communication (through pre-recorded artificial voice) to facilitate communication with the children (Figure 1). One of the main characteristics that differentiate N-MARIA from other assistive robots used in therapies is its ability to move around, as its construction was made based on two motorized wheels and a castor wheel, which gives it the ability to interact spatially with the children. N-MARIA can approach and move away, in addition to carrying out programmed routes. In addition, its control strategies allow movements under command of the therapist or autonomously using concepts of proxemic [10–12].

As an advance of this previous robot, the MARIA T-21 is the new robot to be used also in therapies with DS children through interaction with serious games. Thus, this work addresses the new robot (MARIA T-21) [13], which is shown in Figure 2. This robot incorporates all the features of the robot N-MARIA, however, it presents new functions and characteristics, such as greater robustness, the possibility of projecting images on the floor, table or walls (for the execution of serious games) in addition to activities that stimulate proprioception, postural balance and motor coordination. The robot has also cameras coupled to the robot for image capture for the analysis of gait and joint range of motion, seeking to provide a better quality of life for children with DS and their families.
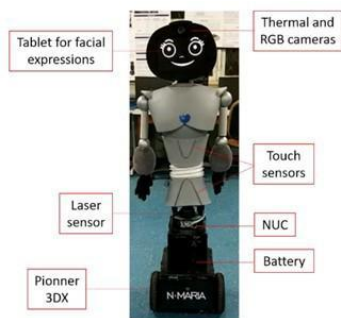
Figure 1. Robot N-MARIA previously developed at UFES/Brazil
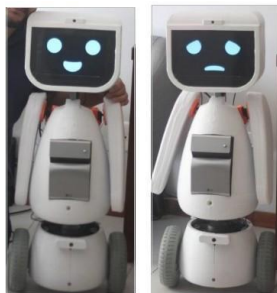
Figure 2. Robot MARIA T-21, which is the new robot developed at UFES/Brazil

The objective of this work is to describe a protocol of serious games implemented in the robot MARIA T-21 as a method for intervention in proprioception, postural balance, and gait of children with DS, aged between 5 and 15 years. This research was authorized by the UFES' Ethics Committee (number 1,121,638) to verify the efficiency of the developed system.

II. MATERIALS AND METHODS

A. Participants

The sample consists of two groups of individuals that interacts with the robot: the first group is composed of children and teenagers of both genders, with a clinical diagnosis of DS, aged between 5 and 15 years. These children are assisted by the Association of Parents and Friends of the Exceptional (APAE/Brazil) (from the cities of Vitoria and Vila Velha), Association of Parents, Friends, and People with Down Syndrome of Espirito Santo (Vitoria Down), and by clinics that provide care for children with DS in the metropolitan area of Vitoria/Brazil. The control group consists of typical children and teenagers of both genders, aged between 5 and 15 years.

B. Inclusion Criteria

For the first group, only children with a clinical diagnosis of DS are selected, whose parents and/or guardians have authorized them to participate in the study by signing the informed consent form (TCLE). The children of this group understand verbal and/or visual commands directed to them during the games. In addition, their parents/guardian affirm they do not have traumatic experiences or phobias and not use drugs that can interfere in the neurotransmission processes. For the control group, the parents' and/or guardians' permission to participate in the study was defined as an inclusion criterion.

C. Exclusion Criteria

For both groups, children with osteoarticular pathology and/or immobility of the limbs and with the tendency to be aggressive and/or very agitated were defined as exclusion criteria.

D. Protocol for DS children

For the first group, an anamnesis is conducted in the first and last session with the parents and/or guardians of the children, and each child is submitted to a physiotherapeutic evaluation of static and dynamic body balance using the Berg Scale [14], and an assessment of proprioception, muscle tonus and motor coordination (coarse and fine) using the instrument "Fonseca's Psychomotor Battery" [15], which consists of a series of structured observation tests of components of children's psychomotor behavior, divided into seven psychomotor factors: tonicity, balance, lateralization, body notion, spatio-temporal structuring, global praxis, and fine praxis. An analysis of the body images captured by cameras onboard the robot allows verifying the gait and range of motion of their upper and lower limb joints. An instrumented carpet manufactured by the engineering team is also used in the experiments, which contains load cell sensors to analyze the plantar grip during the performance of the tasks in the game "Magic Carpet of Alladin". At the last session, a physical and psychomotor reassessment is conducted to evaluate therapy results.

The protocol consists of twelve interaction sessions with the robot, with the application of two sessions per week, lasting 50 min each, where the child is assisted and receives verbal commands all the time by the physiotherapist.
In this protocol, four games are used in each session, with the "Game of the March" being performed in all sessions

and the other three games chosen randomly among the other seven games described in this work. The duration for each game is 15 min. The physiotherapist explains and demonstrates to the child the correct way to use each game before the start of each one. This procedure is repeated throughout the data collection period or until the child has already learned the correct way to play.

E. Protocol for the control group

For this group, only a physical evaluation is conducted. The cameras onboard the robot capture images during the sessions with the games and activities using the robot.

F. Virtual environments

The description of the serious games that constitute the protocol implemented to the robot is as follows.

F.1. Walking on the Line

The game "Walking on the Line", represented in Figure 3, has the objective of training postural balance, proprioception, and motor coordination, whose images are projected on the floor, with a cliff and a rope that the child must walk on to get to the other side of the cliff. This game consists of three different levels: the first, in which the child must walk through the image of the rope, holding a soft ball until he/she reaches the other side of the cliff. On the second level, the child must walk on the image of the rope holding the ball until the other side of the cliff is reached and, along the way, images of birds appear, in order to be na obstacle to the task. On the third level, the child must walk on the rope image holding the ball until the other side of the cliff is reached and, throughout the walk, a delimited portion of the rope image begins to flash and, after 5 s, it disappears and reappears again after 3 s.
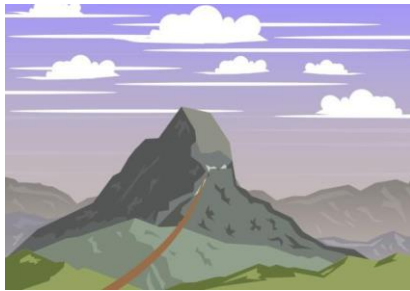

Figure 3. Game "Waling on the Line"

F.2. Jump Rope

The game "Jump Rope" aims at training balance, proprioception, and motor coordination, which includes the projection on the floor of a moving rope for the child to jump (Figure 4). It consists of four levels: the first level features the projection of the rope image for the child to jump, with free time. In the second level, there is a reduction in the time the image of the rope appears on the floor for the child to jump. On the third level, the speed of the rope's projection is the same as the first level, with the addition of the projection of a ball thrown towards the child, so that he/she "catches" it while jumping the rope. At the fourth level, a virtual child is added to the projection to perform the activity at the same time as the child to stimulate competition.
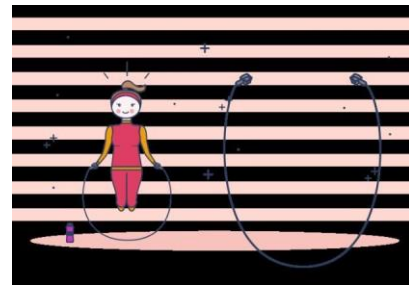

Figure 4. Serious Game "Jump Rope"

F.3. Hopscotch

The game "Hopscotch" aims to train postural balance, proprioception, and motor coordination, and has the projection of the image of hopscotch on the floor. It consists of four levels: at the first level, the child must jump the hopscotch, according to the number drawn (by the robot) on the floor (Figure 5). On the second level, the child must jump over the hopscotch (in this case, instead of numbers, a footprint appears, some directed forward, others directed towards the right side, and others towards the left side). In each "cell" of the hopscotch the child must jump with his/her feet in the direction indicated by the footprints. In the third level, there is a reduction in the time to perform the task of level 2. In the fourth level, a virtual child is added to the projection to stimulate competition.
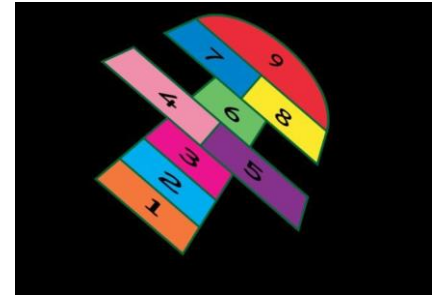

Figure 5. "Hopscotch"

F.4. Hammer of Strength

The game "Hammer of Strength" aims to train postural balance, proprioception, motor coordination, modular stereotypes, and the training of divided and shared attention. It is composed of the projection of images of a target for the child to step in with both feet simultaneously after a jump, and of a column (projected on the wall) displaying the score and a point marker that moves along that column. It is composed of 4 levels: at the first level, the child must jump with the two feet on the mark and observe his/her score (Figure 6). In the second level, the child must perform the jump at the same time that a voice command issued by the robot asks for another task to be performed together, such as catching a soft ball (thrown by the therapist). On the third level, the child must perform the jump with unimodal support, and on the fourth level, a virtual child is added to the projection to stimulate competition.
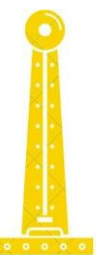

Figure 6. Game "Hammer of Strength"

F.5. Music Therapy

The games with "Music Therapy" aim at the training of proprioception, motor coordination, postural balance, and divided and shared attention. These games feature a projection of images related to the narrative emitted by the robot, such as, for example, forests, beach, tasks request and others. The robot then draws the scenarios contained in the narrative emitted by the child, and moves around the room close to the child. The child must walk around the room next to the robot and explore the projected scenarios and perform the requested tasks. The following are examples of tasks: 1) The robot plays a suspense song while the child explores the projected environment (forest) and, at a given planned moment, the child finds one or more animals (which emit sounds). The robot can also request a task for the child (for instance, escape instructions – if it is a large and potentially dangerous animal, such as a jaguar –, feed the animal, and give instructions to take the animal to a specified place).

Images of landscapes and peaceful and happy moments when playing classical instrumental music (and observe how the child behaves, including motor assessment. 3) Projection of parts on the table (geometric shapes with different colors) and, following the rhythm of the song, the therapist shows a sequence of touches on the parts and asks the child to repeat the sequence.

F.6. Just Dance

The game "Just Dance" aims to train proprioception, postural balance, motor coordination, divided attention, and shared attention. This game features the projection of an avatar, which performs a choreography while playing a children song that should be followed by the child (Figure 7). To aid in the accomplishment of this task, in addition to the avatar, footprints are also projected on the floor, where the child should step to guide his/her movements in a way that they are more similar to the avatar's choreography. The selection of the songs is made considering dance and evocative melodies of parts of the body, such as raising hands, jumping with one foot, touching the head, turning, and others.

Figure 7. Game "Just Dance"

F.7. Marching

The "Marching" game aims to train the gait phases, which has the projection on the floor of a path through which the child must walk until reaching the projection of a chest at the end of the path (Figure 8). When opening that chest, a projection of a virtual child explains to the child how to play the game and give voice commands to the child. Then there is a projection of a path containing images of footprints and voice commands to guide the child on the correct way to step on the footprints. The execution time of the requested tasks is free, and the game takes 15 min to be completed. It is important to notice that the robot has the

ability to rotate and allow the projection of the path to continue throughout the experiment room.

Figure 8. Serious Game "Marching"

F.8. Magic Carpet of Alladin

The game "Magic Carpet of Alladin" aims to train proprioception, motor coordination, stimulate contact with new textures and stimulate the touch by the children. The carpet has five different areas, containing different textures, all with load cells for analysis of the plantar grip. Its regions act as direction controls, according to the projection in front of the child and the voice commands issued by the robot, guiding the child to an adventure. The child must avoid obstacles, such as birds, airplanes, and rain clouds (when the adventure is in the sky, figure 9), and rocks, fishes and currents (when the carpet runs in water adventures). By positioning himself/herself in the left of the carpet, for example, the child will move to the left his/her carpet in the adventure. The center of the carpet will be neutral and correspond to the command to keep the course stable. Therefore, depending on the obstacle or the child's finds when moving to one of the four carpet regions surrounding its center, the carpet moves in the corresponding direction. In case of resistance to any of the textures, and consequent absence of the child's displacement, the carpet collides with the obstacles. At all moments, the robot stores information regarding the time duration on the carpet region, in addition to a physiognomy of resistance/repulsion to the touch of any carpet texture.

Figure 9. "Magic Carpet of Alladin"

III. PILOT TEST

A pilot test of child-robot interaction was carried out with two children, one with Down Syndrome and the other with typical development. The two children initially showed fear of the robot, which may be related to the dynamics of presenting the robot to the child used by the research team, in which the robot entered the room when the child was already in it. The child with DS performed approximately one hour of interaction with the robot and during this period,

he performed the "What is the Card" (not described in this work) and the "Marching", showing good resourcefulness and interest in this (Figure 10) and difficulty understanding of the commands in that (Figure 11). In addition, she showed curiosity and na affectionate relationship with MARIA T21, calling her a friend and at the end of the session she cried because she did not want to go.

Figure 10. Pilot study scene: child-robot interaction through serious game "What is the Card"0

Figure 11. Pilot study: child-robot interaction with serious game "Marching"

The child of typical development performed approximately twenty minutes of interaction with MARIA T21, using only the "What is the Card", showing resourcefulness and reported to the mother that she would like to play with the robot again. In the next test we will start the session with the robot already inside the room.

IV. DISCUSSION

The present work describes a protocol of serious games containing eight games, to be implemented in a study on our new assistive robot, which uses a method for intervention in proprioception, postural balance, and gait of DS children, aged between 5 and 15 years. In the same way as addressed in this work, studies by Srinivasan et al [16] also evaluated the effects of robotic interventions in relation to a standard comparison intervention on coarse and fine motor performance, imitation/praxis, and interpersonal synchrony skills of ASD children. In their study, they observed movement groups when children interacted with robots and performed a variety of imitation games and activities that stimulated postural balance, bilateral motor coordination, imitation, interpersonal synchrony, and manual dexterity during joint action games. According to their results, they verified improvements in coarse motor performance. In relation to the comparison group, which conducted educational and fine motor activities using a table, they verified improvements in fine motor performance of the children. The authors claim the inclusion of goals that promote coarse and fine motor proficiency in therapies for ASD children, due to the perceptual and motor deficiencies of these individuals. They also suggest that bodily activities based on the movement of the whole body, such as rhythm

and robotic therapies, are valuable contexts for promoting motor skills in children with ASD. The French company Leka has created an interactive robot that uses gamification to help children with DS, ASD and multiple disabilities to develop their motor and intellectual skills [17]. Among the games, there are "hide and seek" and a colorful bingo in single or multiplayer versions, which are focused on multi-sensory stimulation. Different applications installed on the robot provides funny and educational games to motivate the children's social interactions, which improved their motor and cognitive coordination, got greater control of emotional skills as well as a great incentive to autonomy. Leka uses several sensors to interpret and respond to the child's interaction through autonomous behaviors, with the goal of helping them to better understand social signals and improve their social skills. Leka contains a monitoring platform where the information is displayed in graphs, allowing parents and caregivers analyze the interaction between the child and the robot, and decide together the development of new activities according to the child's progress [17].

A group of students from a public school in Paraná (Brazil) developed a robot termed Bobô to meet the needs of a student with DS who has voiding dysfunction at the age of 7. The robot is less than 20 cm tall and has two buttons shaped in the form of colored rectangles, one green and one red, which indicate, respectively, yes and no. These buttons are used by the child to make the register for medical follow-up. The robot moves around the school with ease, following a programmed path, made of lines and curves marked on the floor in black and white, which goes from the classroom to the bathroom. The robot also helps the student to have more autonomy. Before, the girl used to get easily lost in the school and needed to be Always accompanied. Now she can go to the bathroom without the company of an adult using the lines marked on the floor to not get lost. "She takes care of the robot, and the robot takes care of her", said the school principal [18].

The neuropsychologist Wilson Bueno developed a robot called Robi to help in the school routine of children with special needs. The robot works as an assistant to the teacher in the classroom and can also be a tool for health professionals, who provide treatments for ASD, DS, dyslexia, speech, and motor dyspraxia, among others. It works as follows: the therapist, caregiver or teacher asks a question, and the child uses a board called "instruction table" to give the answer by pressing a button. If the answer is right, Robi moves on a rug. There are rugs of different themes, according to the work proposal. The tasks include learning at school and also everyday situations, such as putting on clothes. The robot can be also used as a backdrop for working on creativity, speech coordination and logic, in addition to being applied to the study of mathematics and to the reading learning. In the case of children 8 with motor difficulties, it promotes the training of laterality, depth, fine and coarse motor coordination, among other benefits [19].

Bernardini, Porayska-Pomsta, and Smith [20] developed a serious game (Echoes) to help ASD children practice social communication skills. The game was aimed at implementing interactive learning activities in a two- dimensional sensory garden, in addition to an autonomous virtual agent who acts as a social partner for these children. The autonomous virtual agent supports learning in this context. The experimental results showed encouraging trends to improve the sociability of these children.

Abellard and Abellard [21] presented in their study a serious game developed for children suffering from multi-disabilities, for assessment and cognitive training with a focus on knowing their preferences to improve communication between them and the therapist. A 3D environment was created, simulating a forest, in which the child could move and explore according to his/her will. For the authors, the 3D environment provided more possibilities for exploration and motivation for the child. Despite his/her freedom of movement, the child went through certain places where the screen changed, presenting different shapes, colors, and sounds selected at a random way. At the end of the path, the child visualized the objects with the colors, shapes, and sounds he/she had selected, and the results were recorded in a database. The authors emphasized that the specificities of these children must be taken into account when choosing feedbacks and game interfaces.

V. CONCLUSION

The robot MARIA T-21 may be an important tool for recreational therapeutic, providing greater interaction between body and mind, stimulating greater adherence to therapies by children. It is also expected that this research will have social, therapeutic, and scientific relevance, and will also improve and optimize the provision of care services for DS children.

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REFERENCES

[1] A. Tapus, M. Maja, and B. Scassellatti, "The grand challenges in socially assistive robotics," *IEEE Robotics and Automation Magazine*, vol. 14, no. 1, pp. N–A, 2007.

[2] P. Chevalier, G. Raiola, J.-C. Martin, B. Isableu, C. Bazile, and A. Tapus, "Do sensory preferences of children with autism impact an Imitation task with a robot?" in *2017 12th ACM/IEEE International Conference on Human-Robot Interaction -HRI*. IEEE, 2017, pp. 177–186.

[3] A. C. d. S. Lapa, "Análise das significações de pais de crianças com necessidades educativas e de saúdes especiais: estudos de caso," Ph.D. Dissertation, 2010.

[4] L. F. Teixeira, S. J. Olney, and B. Brouwer, "Mecanismos e medidas de espasticidade," *Fisioterapia e Pesquisa*, vol. 5, no. 1, pp. 4–19, 1998.

[5] A. C. Coppede, A. C. d. Campos, D. C. C. Santos, and N. A. C. F. Rocha, "Desempenho motor fino e funcionalidade em crianças com síndrome de Down," *Fisioterapia e Pesquisa*, vol. 19, no. 4, pp. 363–368, 2012.

[6] A. B. Souza, S. Assis, L. K. Rezende, and R. Cymrot, "Caracterização do desempenho funcional de indivíduos com síndrome de down," *Rev Ter Ocup Univ*, vol. 26, no. 1, pp. 102–8, 2015.

[7] J. C. Leite, J. C. D. J. Neves, L. G. V. Vitor, and D. S. Fujisawa, "Controle postural em crianças com síndrome de down: avaliação do equilíbrio e da mobilidade funcional," *Revista Brasileira de Educação Especial*, vol. 24, no. 2, pp. 173–182, 2018.

[8] S. Beqaj, E. E. Tërshnjaku, M. Qorolli, and V. Zivkovic, "Contribution of physical and motor characteristics to functional performance in children and adolescents with down syndrome: a preliminary study," *Medical science monitor basic research*, vol. 24, p. 159, 2018.

[9] B. M. Mattos and C. D. F. Bellani, "A importância da estimulação precoce em bebês portadores de síndrome de Down: revisão de literatura," *Revista Brasileira de Terapias e Saúde*, vol. 1, no. 1, pp. 51–63, 2010.

[10] C. Valadão, E. Caldeira, T. Bastos-Filho, A. Frizera-Neto, and R. Carelli, "A new controller for a smart walker based on human-robot formation," *Sensors*, vol. 16, no. 7, p. 1116, 2016.

[11] B. V. P., "Desenvolvimento de um robô socialmente assistivo com controle baseado em comportamento de seleção de ação para intervenção com crianças com TEA, Master's Thesis, Universidade Federal do Espírito Santo, Vitória, ES, 2018.

[12] C. Goulart, C. Valadão, E. Caldeira, and T. Bastos, "Brain signal evaluation of children with autism spectrum disorder in the interaction with a social robot," *Biotechnology Research and Innovation*, vol. 3, no. 1, pp. 60–68, 2019.

[13] S. S. C. E. C. Panceri J.A.C., Freitas E.V.S. and B.-F. T.F., "Proposal of a new socially assistive robot with embedded serious games for therapy with children with autistic spectrum disorder and down syndrome," in *Congresso Brasileiro de Engenharia Biomédica*, Vitória, 2020, pp. 1865–1870.

[14] K. O. Berg, S. L. Wood-Dauphinee, J. I. Williams, and B. Maki, "Measuring balance in the elderly: validation of an instrument." *Canadian jornal of public health, Revue canadienne de sante publique*, vol. 83, pp. S7–11, 1992.

[15] V. da Fonseca, *Manual de observação psicomotora: significação psiconeurológica dos fatores psicomotores*. WAK, 2019.

[16] S. M. Srinivasan, M. Kaur, I. K. Park, T. D. Gifford, K. L. Marsh, and A. N. Bhat, "The effects of rhythm and robotic interventions on the imitation/ praxis, interpersonal synchrony, and motor performance of children with autism spectrum disorder (ASD): a pilot randomized controlled trial," *Autism research and treatment*, vol. 2015, 2015.

[17] O. Digital, "Robô ajuda crianças com autismo e síndrome de Down," 2016. [Online]. Available: encurtador.com.br/abDG8

[18] K. Bembatti, "Conheça o Bobô, o robô-anjo que dá uma aula de inclusão e solidariedade", 2016. [Online]. Available: gazetadopovo.com.br/ vida-e-cidadania/conheca-o-bobo-o-robo-anjo-que- da-uma-aula-de-inclusao-e-solidariedade-9kmvcrwv146x9ahxjinjfzqtp/

[19] F. de S ao Paulo, "Robô facilita aprendizado de crianças com necessidades especiais," 2017. [Online]. Available: Robô facilita aprendizado de crianças com necessidades especiais - 20/08/2017 - Mercado - Folha de São Paulo (uol.com.br)

[20] S. Bernardini, K. Porayska-Pomsta, and T. J. Smith, "Echoes: An intelligent serious game for fostering social communication in children with autism," *Information Sciences*, vol. 264, pp. 41– 60, 2014.

[21] P. Abellard and A. Abellard, "Serious games adapted to children with profound intelectual and multiple disabilities," in 2017 9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games). IEEE, 2017, pp. 183–184.