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Robot-mediated therapy: Emotion Recognition and Social Skills Training for children with ASD. Analysis of the use of Zoomorphic Robot Brian- preliminary reports

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Abstract

Introduction: The study aimed to evaluate the effectiveness of the zoomorphic robot Brian in the therapy of children diagnosed with autism spectrum disorder (ASD) compared to standard therapist-led interventions. The assessment focused on the child's level of interest in the robot, willingness to respond to verbal commands given by the robot, adaptive behaviors, social communication, imitation during play, and recognition of emotional states presented by the robot.

Materials and methods: The study included fourteen children, with a total of 116 therapy sessions conducted. Each child participated in four sessions with the zoomorphic robot and four sessions with a therapist. During the sessions, the children's responses to verbal commands, ability to recognize emotions, and skills in social communication and imitation were evaluated.

Results: The study showed a significantly greater willingness of autistic children to respond to verbal commands given by the robot than to the same commands spoken by the therapist. Additionally, children with ASD demonstrated better recognition and naming of emotional states displayed on the robot's face compared to those on a human face.

Conclusions: In interaction with the robot, autistic children acquired and exhibited desired social communication and imitation behaviors more quickly than in traditional therapy conducted by a therapist. These results suggest that robots may serve as an effective tool to support the therapy of children with ASD.

Keywords: robot-assisted therapy, human-robot interaction, social robots, autism spectrum disorder

Streszczenie

Wstęp: Badania miały na celu ocenę skuteczności robota zoomorficznego Brian w terapii dzieci z diagnozą autyzmu dziecięcego (ASD) w porównaniu ze standardowym oddziaływaniem z udziałem terapeuty. Ocenie poddano poziom zainteresowania dziecka robotem, gotowość dziecka do reagowania na komunikaty słowne wypowiadane przez robota, zachowania adaptacyjne, komunikację społeczną i naśladownictwo podczas zabawy, a także rozpoznawanie stanów emocjonalnych prezentowanych przez robota.

Materiały i metody: Badaniem objęto czternaścioro dzieci, przeprowadzono łącznie 116 sesji terapeutycznych. Każde dziecko uczestniczyło w czterech spotkaniach z robotem zoomorficznym oraz czterech spotkaniach z terapeutą. Podczas sesji oceniano reakcje dzieci na komunikaty werbalne, zdolność rozpoznawania emocji oraz umiejętności w zakresie komunikacji społecznej i naśladownictwa.

Wyniki: Przeprowadzone badania wykazały wyraźnie większą gotowość dzieci autystycznych do reagowania na komunikaty słowne wypowiadane przez robota niż na te same komunikaty usłyszane od terapeuty. Ponadto dzieci z ASD lepiej rozpoznawały i nazywały stany emocjonalne prezentowane na twarzy robota niż na twarzy ludzkiej.

Wnioski: W kontakcie z robotem dzieci autystyczne szybciej przyswajały i wykazywały pożądane zachowania w zakresie komunikacji społecznej i naśladownictwa podczas zabawy niż w tradycyjnej terapii prowadzonej przez terapeutę. Wyniki sugerują, że roboty mogą stanowić skuteczne narzędzie wspomagające terapię dzieci z ASD.

Słowa kluczowe: autyzm dziecięcy, roboty społeczne, terapia wspomagana robotem, interakcja człowiek robot

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that begins in early childhood. It is characterized by difficulty in reading and communicating feelings, disorders in establishing relationships, impoverished and stereotyped behavior. The possible disabilities associated with ASD are: depression, anxiety and agressive behavior.

Autistic people undergo various forms of therapy (behavioral, educational interventions), which can significantly improve their functioning. The extent of achievable symptomatic improvement depends, among other things, on how early the disorder is diagnosed and how early the child receives an appropriate therapeutic program to support their development.

New technologies can help children with ASD communicate and enter interactions with others [1–4]. One of the technologies in use is robot-assisted autism therapy (RAAT) [5].

RAAT (Robot Assisted Autism Therapy) finds use in supporting the diagnostic process in childhood autism, improving eye contact and focusing a child's gaze on a human face (gaze) [6,7], treating disturbed developmental areas of children with ASD (e.g., sensory development, emotional and social development) [8–10], conducting alternating conversation (turn-taking) [11,12].

Studies have also shown higher levels of self-knowledge and trust when in contact with a visually simple robot (simplified humanoid robot [CommU]) as compared to interacting with a human therapist [13]. Therapy with a robot also develops imitation in play, sharing joint attention [14–18].

Reports indicate that the intelligence level of children with ASD may be a relevant factor in the effectiveness of social skills therapy in autism. A study by Pioggia et al. suggests that children with an autism diagnosis and low IQ may not benefit sufficiently from RAAT [19]. Shamsuddin on the other hand, observed progress in the acquisition of social skills in therapy administered with a robot therapist in children with low IQ [20].

Marino's study on emotion recognition involved fourteen children (ages 4-8) with a diagnosis of ASD [21]. They participated in 10 sessions of Cognitive Behavioral Therapy (CBT), conducted in a group setting with or without the help of a NAO social robot. The robot, which acted as a co-therapist, provided emotional reinforcement, guidance, and prompts. Pre- and post-intervention assessments were conducted using the Test of Emotion Comprehension (TEC) and Emotional Lexicon Test (ELT). The results showed a meaningful, statistically significant improvement in contextual emotion recognition and improved emotion comprehension in the group utilizing the NAO social robot. In children in the RG (Robot Group), significant improvement occurred not only in the recognition of the five basic emotions (anger, disgust, fear, happiness and sadness), but also in shame. The pre-intervention evaluation showed that none of the CG (Control Group) children and only two of the RG children were able to recognize and explain what shame is. After the 10-week intervention, all of the children in RG were able to correctly recognize the emotion of shame, while none of the children in KG were able to correctly recognize this emotion. The authors [21] posed a hypothesis to be clarified in future studies: robot-assisted therapy

increased the ability to recognize other emotions as well, and generalization to other emotions can be applied. Interestingly, in the RG, all children achieved the highest score in ELT, learning one to three new emotions, while in the control group, no child achieved the highest score nor did they learn even one new emotion.

Different types of robots are used in the therapy of children with ASD: humanoid, e.g. Robot [22], Infanoid, Keepon, KASPAR [10,23], NAO, CommU, Actroid-F [17] as well as zoomorphic robots [24–27]. Studies have shown that ASD patients can focus more easily on robotic animals than on a human therapist [17]. Studies by Wood et al. [23] were inspired by the Non-Directive Play Therapy approach. Zoomorphic robot therapy was tested in a group of children with childhood autism in an English school. A zoomorphic dog robot was used in the study. The children's progress was analyzed in three dimensions: naming, playing, reasoning. The results of the evaluation showed the suitability of the method to meet the needs and abilities of each child. Children who actively played socially using the zoomorphic robot gradually experienced higher levels of play and built more robot-related reasoning.

The other reports show that zoomorphic robots such as a seal, rabbit, dinosaur or parrot make children curious, engage in interaction, develop touch, encourage stroking and making physical contact [28]. Hence the choice of a robotic rabbit for our study.

The goal of our research was to construct and apply to the therapy of autism in children a robot that would be simple, yet attract the child's attention, one that does not arouse fear and encourages social interaction. The purpose of the research undertaken in this work was to test whether the zoomorphic rabbit robot Brian, constructed by the specialists of our research team, would find application in the therapy of social behavior and the ability to recognize emotional states in children with ASD, and if it would be a valuable addition to standard therapy in ASD.

The authors of this study posed the following research questions:

1. Will the studied group of young patients with ASD be more willing to participate in therapy than before, when the therapeutic work was conducted only with another person?
2. Will the studied children with autism demonstrate good adaptation to the new situation, which coming into contact with the robot Brian will be?
3. Will the studied children with ASD diagnosis show more readiness to respond to verbal messages spoken by the robot than to the same messages heard from the therapist?
4. Will the tested children with autism show better recognition and naming of emotional states on the face of the robotic zoomorphic rabbit Brian than on the human face?
5. Will the tested children with ASD show the desired behaviors of social communication, creativity and imitation during play compared to traditional therapy?

Materials and Methods

1.1 Zoomorphic Robot

The robot was built as part of the project: RPLU.01.02.00-06-0083/16-00 "DreamRobot– support system for autistic children therapy" ("DreamRobot - system wsparcia terapii dzieci autystycznych")

- During the design phase several requirements were addressed:
- Quick reaction towards the behaviour of children. The reaction does not need to be complex.
- Need for manual interaction. The robot should be able to perform hand gestures, shake hands, dance, move, play with a ball and move small items.
- Voice interaction, including following sounds, speaking, singing, reacting to speech and spoken commands, speech synthesis, choosing a male or female voice.
- Soft, tactually pleasant chassis, resistant to falls, shaking and other children's reactions, both positive and negative, with an option to remove the outer covers for washing.
- No triggering factors, including jerky movements, bright colors, loud and surprising sounds while still being engaging and interesting.
- Partially humanoid construction with animal traits while still being far from the uncanny valley.
- Control panel with access to motion controls, voice synthesizers, programmable sequences and tools to create new interactions.

The proposed robot was constructed in the form of a wheeled chassis with an upper body of a cartoon robot rabbit. It was able to perform simple actions using two independent arms with four degrees of freedom each, two in the shoulder, one in the elbow and opening and to close the gripper on light, small objects. The body housed a camera and a distance sensor for detecting nearby objects. The neck was able to move in three axes, which allowed gestures for expressing yes or no, tilting the head in wonder and following the child. The face was a screen that expressed the animated, touch-sensitive face of the robot. A camera, speakers and directional microphones

in the head were used to communicate with the child. The head was topped by a pair of ears able to move forward, back and side to side to further show the robot's emotions. The wheeled chassis was able to move on two independent motors and was stabilised by a rear facing wheel. Two versions of the robot were designed and constructed. Version one is shown in figure 1A below. Version two was sleeker but was missing several degrees of freedom. It is shown in figure 1B below. The tests were performed using version one. More information about construction and software details can be found in [27].

A) *B)*

Figure 1. Both versions of constructed robots (A - version one, B- version two)

1.2 Functional areas evaluated

The research conducted was aimed at a preliminary evaluation of the effectiveness of the zoomorphic rabbit robot Brian in the therapy of children with a diagnosis of ASD, compared to standard interactions with a therapist. Given the complexity of the issue which are autism spectrum disorders, four areas of functioning were chosen for evaluation.

- adaptive and anxiety behaviors,
- social communication and imitation during play,
- the child's level of interest in the robot,
- recognition of emotional states.

1.3 Assessment scales used

The scale for assessing the behavior of children with ASD was developed based on the research method used in the diagnosis of children with suspected autism: the ADOS-2, and an analogous assessment of behavior as in ADOS-2 was adopted: 0 - normal response, 1 - insufficient response, 2 - abnormal response.

Imitation, the child's creativity in play, also the quality of social responses were assessed. The results obtained by each child during the four encounters were described in the Behavioral Observation Scale of the child's interaction with the zoomorphic robot Brian.

Methods presenting different emotional states

The subsequent therapy sessions involved presenting different emotional states on the robot screen and discussions about the emotions felt. The emotional states the studied children were taught to recognize were: joy, sadness, anger, surprise.

Joy

Robot: Look at me. Tell me how am I feeling right now?

0. The child answers: You are cheerful.

Robot: Yes, you are right, I am cheerful.

1. the child gives the wrong answer

Robot: No, think and look at me again.

2. Lack of response by the child.

Robot: Look at me, I am cheerful.

Naming one's own emotions

Robot: Tell me how you feel when you get a gift?

Behavior	Evaluation of Social Communication in an Experimental Tea Party Encounter with Brian the Zoomorphic Robot Rabbit	
Preparing tea	0	Prepares a drink for the rabbit immediately after the question: Will you prepare tea for me?
	1	Prepares the drink after being repeatedly asked by the rabbit.
	2	Lack of reaction despite repeated requests by the robot to prepare tea.
Offering tea	0	Serves tea immediately, after being asked by the rabbit.
	1	Offers after repeated requests by the rabbit for a drink.
	2	Does not offer anything to the rabbit.
Wiping the robot with a towel	0	Wipes with a towel immediately after being instructed by the rabbit: I spilled on my tummy; can you help me wipe it off?
	1	Wipes with a towel after repeated requests by the rabbit.
	2	Does not wipe the rabbit with a towel at all.

Behavior	Quality of Social Responses using the rabbit Brian.	
	0	The child demonstrates a range of appropriate responses, varying according to the social situation and task.
	1	Bizarre, stereotypical reactions to play with the rabbit.
	2	No reaction.

Behavior	Imitation and creativity in play with the rabbit Brian.	
	0	Child spontaneously uses objects in imitation play with rabbit (cups, teapot, wiping with towel).
	1	Child imitates pretend play with the rabbit.
	2	No spontaneous or imitated pretend play with a rabbit.

What kind of face do you have then?
Tell me how you feel when someone yells at you? What kind of face do you have then?

SADNESS
Rabbit: Look at me. Tell me, how am I feeling right now?
0. The child answers: You are sad. The child correctly reads the emotional state presented.
Rabbit: Yes, you are right, I am sad.
1. The child gives an incorrect answer.
Rabbit: No, think and look at me again. The child, after thinking, correctly reads the emotional state presented by the Rabbit.
2. Lack of response by the child.
Rabbit: Look, I am sad.

JOY
Rabbit: Look at me. Tell me, how do I feel now?
0. The child responds: You are cheerful. The child correctly reads the emotional state presented.
Rabbit: Yes, you are right, I am cheerful.
1. The child gives an incorrect answer.
Rabbit: No, think and look at me again. The child, after thinking, correctly reads the emotional state presented by the Rabbit.
2. Lack of response by the child.
Rabbit: Look, I am cheerful.

ANGER
Rabbit: Look at me. Tell me, how do I feel now?
0. The child answers: You are angry. The child correctly reads the emotional state presented by the Rabbit.
Rabbit: Yes, you are right, I am angry.
1. The child gives an incorrect answer.
Rabbit: No, think and look at me again. The child, after thinking, correctly reads the emotional state presented by Rabbit.
2. Lack of response by the child.
Rabbit: Look, I am angry.

SURPRISE
Rabbit: Look at me. Tell me, how do I feel now?
0. The child responds: You are surprised. Correctly identify the emotion presented.
Rabbit: Yes, you are right, I am surprised.
1. The child gives an incorrect answer.
Rabbit: No, think and look at me again. The child, after

thinking, correctly reads the emotional state presented by the Rabbit.

2. Lack of response by the child.

Rabbit: Look, I am surprised.

Description of the research

The study with the zoomorphic robot Brian conducted at NZOZ "Sanus" took place from December 2, 2019 to February 21, 2020. Fourteen children participated in the study, which constituted the clinical group. The children studied were patients of the Sanus Medical Center in Lublin, with a diagnosis of childhood autism (ASD), according to the criteria of ICD-10 and DSM-5 classification (F84.0). Written consent from the parents of each studied child was obtained for their participation in the study. The study was agree by Local Ethical Committee of The Faculty of Medicine at the Medical University, Lublin, number KE 0254/236/2019 and was in accordance Helsinki Declaration of the 1975.

Children with IQs above 80 were qualified for the study due to the level of difficulty of the developed tests and the type of skills tested.

The following inclusion criteria were used in the study:

- children aged 3-10 years;
- a clinical diagnosis of childhood autism based on the Autism Diagnostic Observation Schedule (ADOS-2) test and ICD-10 criteria made by a team of specialists prior to the start of the study with Robot;
- assessment of the severity of clinical symptoms in ADOS-2 from mild (level 1) to moderate, both in social communication and interactions by experienced specialists in the research team (psychiatrist, special educator and clinical psychologist).
- the level of development of active speech at the stage of "sentence speech" and an age-appropriate level of development of passive speech;
- the absence of concomitant hearing and vision disorders and oppositional-defiant behavioral disorders and aggressive behavior;
- a level of intellectual development of not less than 80 IQ tested with the Stanford Binet 5 Scale.
- no neurological treatment or neurological conditions,
- no use of psychiatric medications.

A total of 116 therapy sessions were conducted. Each studied child (patient) had eight analogous and structured meetings using the adopted research method. The study situation was varied only due to the influence of the independent variable, i.e. the presence of the robot. The study consisted of four encounters between the patient and the zoomorphic robot and four encounters between the patient and the therapist, during which a standardized study scheme was carried out. The therapy session with Brian's robot was preceded by a session with the therapist.

All meetings were held in the same room, using the same props (i.e. toys). Parents of the children participating in the study were informed about the purpose of the study and gave written consent for video recording of the meeting.

Self-presentation

In accordance with the methodology, the interaction with the robot was preceded in each child by a familiarization meeting, the purpose of which was to get the children accustomed to a new social situation and an unfamiliar object, due to the fact that children with ASD have difficulty processing large amounts of information and stimuli that may overload them. Self-presentation was essential to create a sense of security in the child who interacts with the robot. This allowed the children to become accustomed to it. Self-presentation is important for children who have never seen a robot before to get used to it.

Social communication and imitation during the thematic game "Meeting at the tea party."

Social functioning was assessed using an ADOS-2 scenario in which the Robot encourages the child to participate in 3 scenes involving toy props: 1. preparing tea, 2. treating the child to tea, 3. cleaning up after tea, wiping the Robot with a towel. This scenario was developed based on a similar model used in the work Kumazaki, Muramatsu, Yokishava [2].

Class scenario:

The robot addresses the child:"Hi, let's play together.

See what I have on the table for you. (The robot extends his hand in front of him, towards the toy basket)

Will you prepare some tea for me?"

No response from the child:

Robot: "I'm thirsty, give me a drink."

Robot: "Very hot tea. Blow on it.

Could you give me a drink again?"

The child serves, the reaction of the robot: "How yummy" - the robot strokes his stomach.

Robot: "Oh dear, I spilled on my tummy, can you wipe it? "

The child wipes the robot's stomach.

Robot: "Thank you, I had a great time playing with you."

At the end of each session, the therapist praised the child for his work and thanked him for participating in the meeting.

Results

The results of the study are presented in graphs (Fig. 2, Fig 3, Fig. 4 and Fig 5) which compare sessions with the Rabbit Robot and therapy sessions with the child working with the therapist without the use of the robot.

3.1. The child's level of interest in the robot Brian

In nine children in the study group, this level was moderate to high. The level of interest in the children increased or remained constant during subsequent meetings. There was no decrease in interest in the Robot by any child. In five children, the level of interest in the Robot from the first to the fourth meeting remained at a high level.

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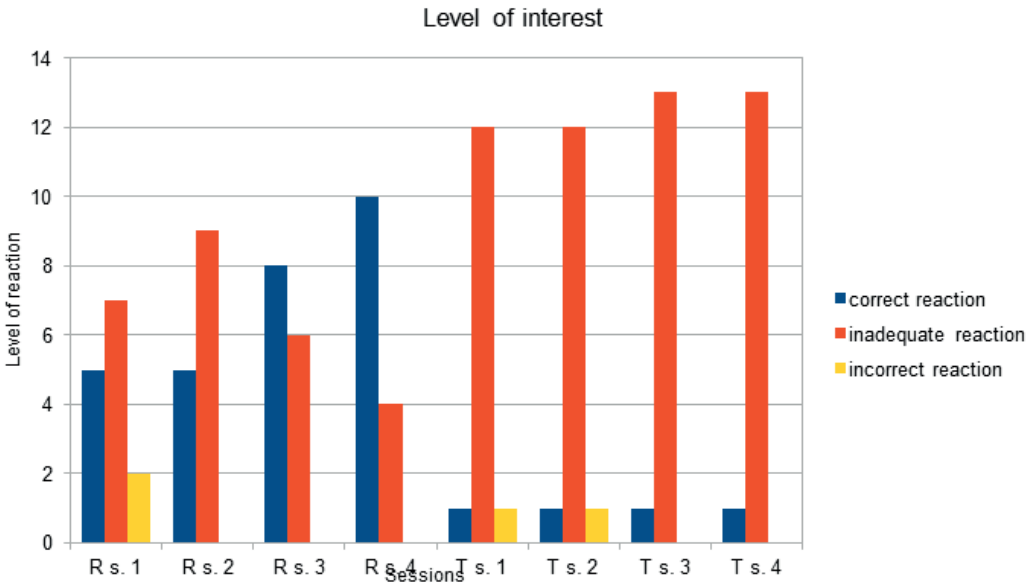

Fig. 2 The level of interest of the studied children. R-sessions with Robot; T- sessions with Therapist

3.2 Adaptive behavior

Seven children showed very positive reactions with their new social interaction partner from the first or second encounter with the robot. Four children showed slight anxiety in the new situation, which was quickly reduced, which was evident as early as the second encounter.

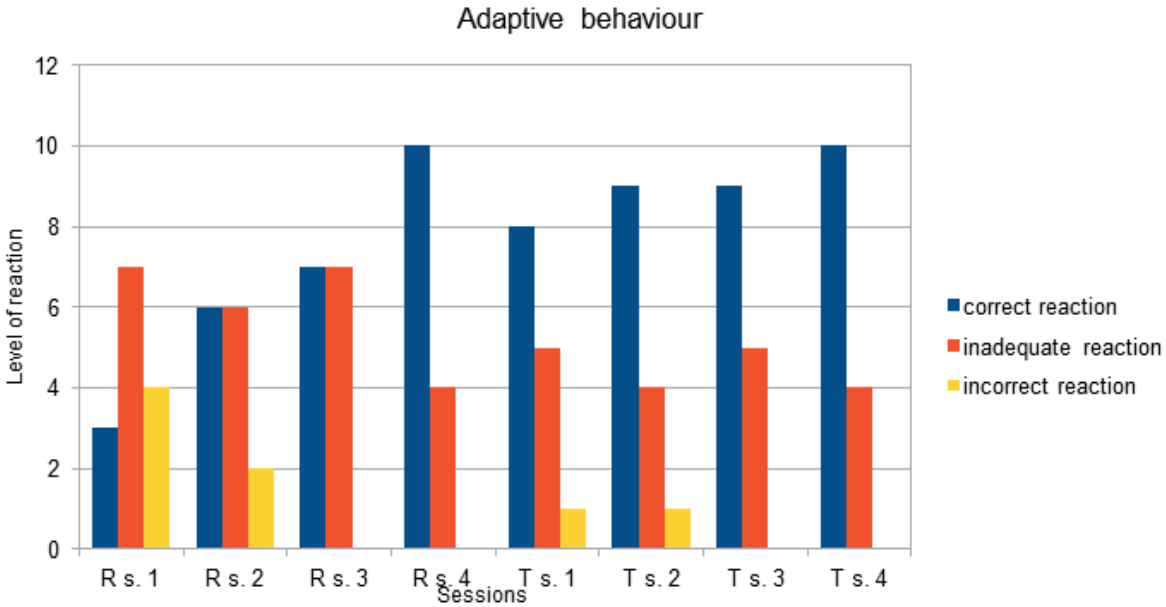

Fig.3 Adaptive Behaviour. R-sessions with Robot; T- sessions with Therapist

3.3 Recognizing emotional states

The autistic children tested showed better recognition and naming of emotional states on the robot's face than on a human face. An increase in correct responses by the children was observed by the 3rd and 4th therapy sessions with the robot and was higher when compared to the sessions with the therapist. Six children correctly recognized three or four emotions on the robot's face over the course of all four meetings.

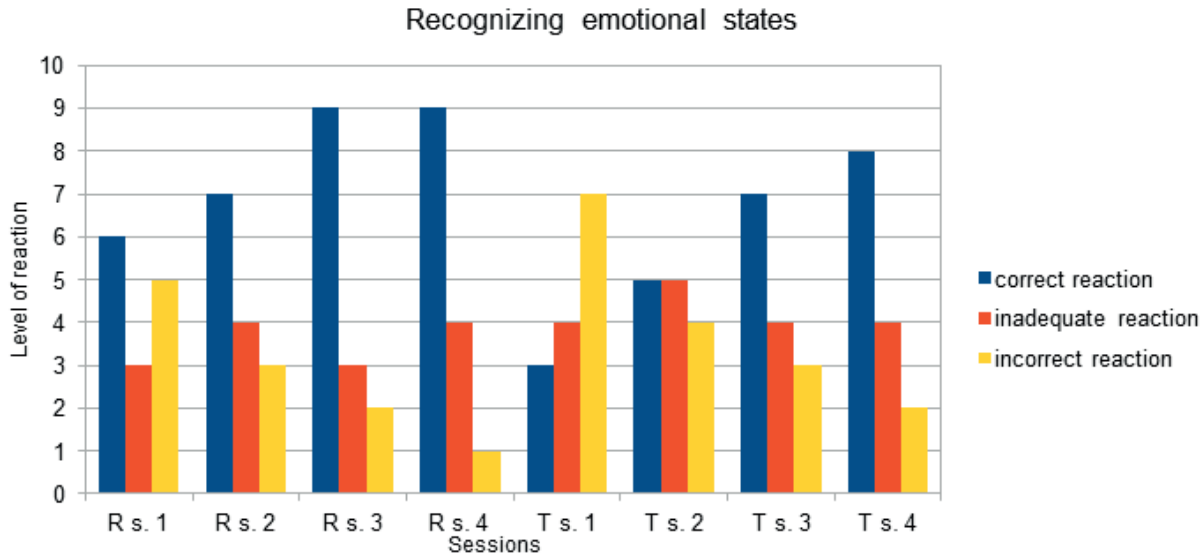

Fig.4. Recognizing of emotional states. R-sessions with Robot; T- sessions with Therapist

3.4 Social communication and imitation during the themed game "Tea Party Meeting"

During therapy sessions using the rabbit robot Brian, greater progress in social communication, assessed as engagement in thematic play, was observed in the study children with an autism diagnosis. The children spontaneously used objects-props in play.

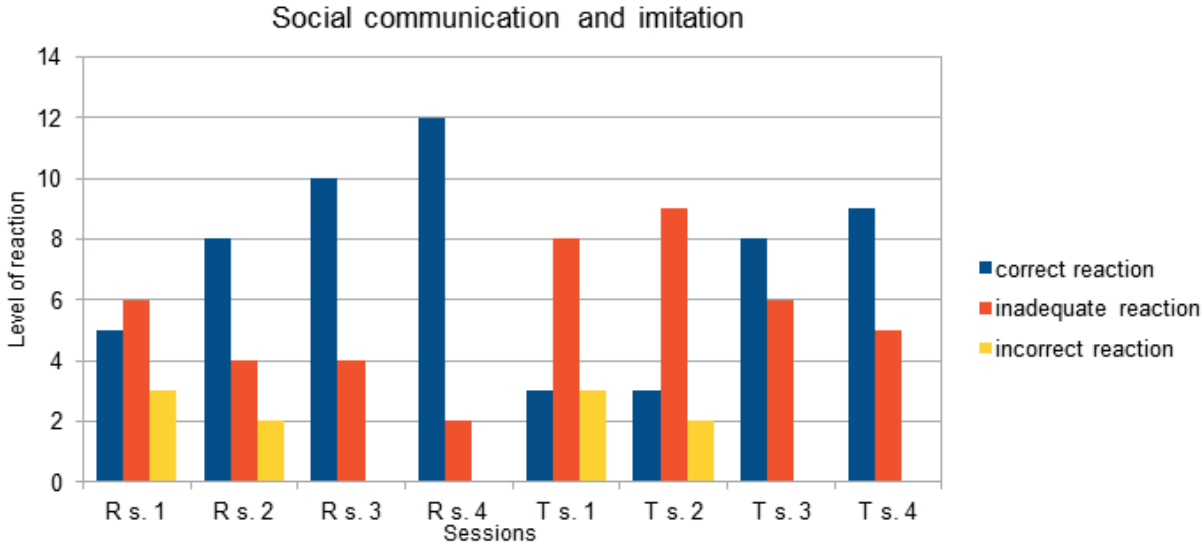

Fig. 5. Social comunication and imitation. R-sessions with Robot; T- sessions with Therapist

Discussion

The results of our experiment showed that the zoomorphic robot Brian is a valuable therapeutic tool in the studied children with ASD, which brought many benefits to the standard therapy, which was previously carried out by the psychologist and special educator therapist. Our study showed improvements in the mental state of patients with ASD primarily in the areas of emotion recognition and social communication (imitation, creativity, thematic play in preparing tea with toy props). The results obtained are consistent with reports from literature, where the participation of the robot in ASD therapy significantly improved the results in the studied areas of social skills [13,15,29,30].

The research results obtained in this work correspond with those of [21]. A study by these authors on the science of emotional states in children with ASD, showed a significant improvement in emotion recognition and improved understanding of emotions in the study group using the NAO social robot.

It is important to answer the question of what type of interaction and emotions presented by the robot to choose for children with ASD, so that the therapy is as effective as possible. "Higher levels of stimulation" can be defined as more complex interaction from robots, such as multimodal stimulation (e.g., looking and pointing, looking and touching). "Lower levels of stimulation" can be defined as simpler interaction on the part of the robots, such as stimulation alone (e.g., only looking, only pointing, only touching). Observing our research, we found that teaching children complex social interactions, such as imaginative play with a robot to frequent a tea party, prepare a treat and clean up afterwards, was met with great curiosity and engagement on the part of young patients. Similar results were obtained in their study by [14] where "higher levels of stimulation" were more beneficial in the acquisition of new social skills for patients with ASD. This is an interesting observation for the planning of our future research and the choice of exercises presented.

On the basis of the observations from our study, a zoomorphic robot seems to be a great tool to encourage contact, learning new skills and engaging in joint activities. You can use it to encourage a child to talk or perform tasks. Of course, it will not replace either building closeness with a parent or working with a therapist; rather, it is meant to serve as a co-therapist and friendly companion in play.

A study of the use of the rabbit Brian with children with ASD diagnosis and intellectual disabilities is planned to be undertaken at Sanus Medical Center, due to inconclusive results in the literature.

Conclusions

The results obtained from the study of fourteen children who participated in 116 therapy sessions in the research experiment with the zoomorphic robot rabbit Brian indicate:

1. A high level of interest in the robot on the part of children with autism. In nine children in the study group, the level was moderate to high. The study showed that the children's level of interest in the zoomorphic robot increased or remained constant during subsequent meetings.
2. The studied children with autism showed good or very good adaptation to the new situation of coming into contact with the robot Brian. Showing the studied children the robot rabbit and participating in the initial phase of self-presentation was a significant factor in promoting adaptation.
3. The conducted research shows that the examined autistic children are clearly more ready to respond to verbal messages spoken by the robot than to the same messages heard from the therapist.
4. Tested children with ASD show better recognition and naming of emotional states on the face of the robot than on the human face. Six children correctly recognized three or four emotions on the robot's face over the course of all four encounters.
5. The studied children with ASD in contact with the robot, compared to the traditional form of therapy, more quickly acquire and demonstrate the desired social communication and imitation behavior during play.
6. The results obtained need to be validated in a larger group of children. A future study is planned to investigate the use of the Rabbit Brain model with children diagnosed with ASD and intellectual disabilities.

Conflict of interest

The authors have declared no conflict of interest.

References:

1. Costescu CA, Vanderborght B, David DO. The Effects of Robot-Enhanced Psychotherapy: A Meta-Analysis. Review of General Psychology. 2014 Jun;18(2):127–36.
2. Kumazaki H, Muramatsu T, Yoshikawa Y, Yoshimura Y, Ikeda T, Hasegawa C, et al. Brief Report: A Novel System to Evaluate Autism Spectrum Disorders Using Two Humanoid Robots. J Autism Dev Disord. 2019 Apr;49(4):1709–16.
3. Schadenberg BR, Neerincx MA, Cnossen F, Looije R. Personalising game difficulty to keep children motivated to play with a social robot: A Bayesian approach. Cognitive Systems Research. 2017 Jun;43:222–31.
4. Yuan F, Klavon E, Liu Z, Lopez RP, Zhao X. A Systematic Review of Robotic Rehabilitation for Cognitive Training. Front Robot AI. 2021 May 11;8:605715.
5. Szymona B, Maciejewski M, Karpiński R, Jonak K, Radzikowska-Büchner E, Niderla K, et al. Robot-Assisted Autism Therapy (RAAT). Criteria and Types of Experiments Using Anthropomorphic and Zoomorphic Robots. Review of the Research. Sensors. 2021 May 27;21(11):3720.
6. Andrist S, Mutlu B, Tapus A. Look Like Me: Matching Robot Personality via Gaze to Increase Motivation. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems [Internet]. Seoul Republic of Korea: ACM; 2015 [cited 2024 Nov 16]. p. 3603–12. Available from: https://dl.acm.org/doi/10.1145/2702123.2702592
7. Cao W, Song W, Li X, Zheng S, Zhang G, Wu Y, et al. Interaction With Social Robots: Improving Gaze Toward Face but Not Necessarily Joint Attention in Children With Autism Spectrum Disorder. Front Psychol. 2019 Jul 5;10:1503.
8. Bharatharaj J, Huang L, Mohan R, Al-Jumaily A, Krägeloh C.

Robot-Assisted Therapy for Learning and Social Interaction of Children with Autism Spectrum Disorder. Robotics. 2017 Mar 14;6(1):4.
9. Rakhymbayeva N, Amirova A, Sandygulova A. A Long-Term Engagement with a Social Robot for Autism Therapy. Front Robot AI. 2021 Jun 16;8:669972.
10. Robins B, Dautenhahn K, Boekhorst RT, Billard A. Robotic assistants in therapy and education of children with autism: can a small humanoid robot help encourage social interaction skills? Univ Access Inf Soc. 2005 Dec;4(2):105–20.
11. David DO, Costescu CA, Matu S, Szentagotai A, Dobrean A. Effects of a Robot-Enhanced Intervention for Children With ASD on Teaching Turn-Taking Skills. Journal of Educational Computing Research. 2020 Mar;58(1):29–62.
12. Soleiman P, Moradi H, Mahmoudi M, Teymouri M, Pouretemad HR. Teaching Turn-Taking Skills to Children with Autism using a Parrot-Like Robot. arXiv preprint arXiv:210112273. 2021;
13. Kumazaki H, Warren Z, Swanson A, Yoshikawa Y, Matsumoto Y, Yoshimura Y, et al. Brief Report: Evaluating the Utility of Varied Technological Agents to Elicit Social Attention from Children with Autism Spectrum Disorders. J Autism Dev Disord. 2019 Apr 1;49(4):1700–8.
14. Anzalone SM, Tilmont E, Boucenna S, Xavier J, Jouen AL, Bodeau N, et al. How children with autism spectrum disorder behave and explore the 4-dimensional (spatial 3D+time) environment during a joint attention induction task with a robot. Research in Autism Spectrum Disorders. 2014 Jul;8(7):814–26.
15. Pennisi P, Tonacci A, Tartarisco G, Billeci L, Ruta L, Gangemi S, et al. Autism and social robotics: A systematic review: Autism and social robotics. Autism Research. 2016 Feb;9(2):165–83.
16. Scassellati B, Boccanfuso L, Huang CM, Mademtzi M, Qin M, Salomons N, et al. Improving social skills in children with ASD using a long-term, in-home social robot. Sci Robot. 2018 Aug 22;3(21):eaat7544.
17. Zheng Z, Young EM, Swanson AR, Weitlauf AS, Warren ZE, Sarkar N. Robot-Mediated Imitation Skill Training for Children With Autism. IEEE Trans Neural Syst Rehabil Eng. 2016 Jun;24(6):682–91.
18. Zheng Z, Nie G, Swanson A, Weitlauf A, Warren Z, Sarkar N. A Randomized Controlled Trial of an Intelligent Robotic Response to Joint Attention Intervention System. J Autism Dev Disord. 2020 Aug;50(8):2819–31.
19. Pioggia G, Sica ML, Ferro M, Igliozzi R, Muratori F, Ahluwalia A, et al. Human-Robot Interaction in Autism: FACE, an Android-based Social Therapy. In: RO-MAN 2007 - The 16th IEEE International Symposium on Robot and Human Interactive Communication [Internet]. Jeju, South Korea: IEEE; 2007 [cited 2024 Nov 16]. p. 605–12. Available from: http://ieeexplore.ieee.org/document/4415156/
20. Shamsuddin S, Yussof H, Mohamed S, Hanapiah FA, Ismail LI. Stereotyped behavior of autistic children with lower IQ level in HRI with a humanoid robot. In: 2013 IEEE Workshop on Advanced Robotics and its Social Impacts [Internet]. Tokyo, Japan: IEEE; 2013 [cited 2024 Nov 16]. p. 175–80. Available from: http://ieeexplore.ieee.org/document/6705525/
21. Marino F, Chilà P, Sfrazzetto ST, Carrozza C, Crimi I, Failla C, et al. Outcomes of a Robot-Assisted Social-Emotional Understanding Intervention for Young Children with Autism Spectrum Disorders. J Autism Dev Disord. 2020 Jun;50(6):1973–87.
22. Ricks DJ, Colton MB. Trends and considerations in robot-assisted autism therapy. In: 2010 IEEE International Conference on Robotics and Automation [Internet]. Anchorage, AK: IEEE; 2010 [cited 2021 Apr 18]. p. 4354–9. Available from: http://ieeexplore.ieee.org/document/5509327/
23. Wood LJ, Zaraki A, Robins B, Dautenhahn K. Developing Kaspar: A Humanoid Robot for Children with Autism. Int J of Soc Robotics. 2021 Jun;13(3):491–508.
24. Coeckelbergh M, Pop C, Simut R, Peca A, Pintea S, David D, et al. A Survey of Expectations About the Role of Robots in Robot-Assisted Therapy for Children with ASD: Ethical Acceptability, Trust, Sociability, Appearance, and Attachment. Sci Eng Ethics. 2016 Feb;22(1):47–65.
25. Kim ES, Berkovits LD, Bernier EP, Leyzberg D, Shic F, Paul R, et al. Social Robots as Embedded Reinforcers of Social Behavior in Children with Autism. J Autism Dev Disord. 2013 May;43(5):1038–49.
26. Nakadoi Y. Usefulness of Animal Type Robot Assisted Therapy for Autism Spectrum Disorder in the Child and Adolescent Psychiatric Ward. In: Otake M, Kurahashi S, Ota Y, Satoh K, Bekki D, editors. New Frontiers in Artificial Intelligence [Internet]. Cham: Springer International Publishing; 2017 [cited 2021 Mar 17]. p. 478–82. (Lecture Notes in Computer Science; vol. 10091). Available from: http://link.springer.com/10.1007/978-3-319-50953-2_35
27. Niderla K, Maciejewski M. Construction of a zoomorphical robot for rehabilitation of autistic children. J Phys: Conf Ser. 2021 Feb 1;1782(1):012024.
28. Clabaugh C, Mahajan K, Jain S, Pakkar R, Becerra D, Shi Z, et al. Long-Term Personalization of an In-Home Socially Assistive Robot for Children With Autism Spectrum Disorders. Front Robot AI. 2019 Nov 6;6:110.
29. De Korte MW, van den Berk-Smeekens I, van Dongen-Boomsma M, Oosterling IJ, Den Boer JC, Barakova EI, et al. Self-initiations in young children with autism during Pivotal Response Treatment with and without robot assistance. Autism. 2020 Nov;24(8):2117–28.
30. Van Otterdijk M, De Korte M, Van Den Berk-Smeekens I, Hendrix J, Van Dongen-Boomsma M, Den Boer J, et al. The Effects of Long-Term Child–Robot Interaction on the Attention and the Engagement of Children with Autism. Robotics. 2020 Sep 28;9(4):79.

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