Deploy Social Assistive Robot to develop symbolic play and imitation skills in students with Autism Spectrum Disorder

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2022 IEEE Global Engineering Education Conference (EDUCON) | 978-1-6654-4434-7/22/$31.00 ©2022 IEEE | DOI: 10.1109/EDUCON52537.2022.9766762

***Abstract*—In the current study, we present how robot-based interventions can improve symbolic play and imitation skills in children with ASD (Autism Spectrum Disorder) by increasing their eye contact, attention, imitation skills, and engagement with a robot. Specifically, we deploy the humanoid NAO 6 (SoftBank Robotics) to enrich ASD students' symbolic play skills through six education applications developed in Choregraphe software platform. The applications were evaluated in pilot studies with 5 students (2 girls and 3 boys, aged 7-10 years) in a Special Primary School for Children with Autism, for 3 months (Nov2020-Jan2021), in which they constantly interacted with the NAO. Initial results reveal improvements in eye contact, attention, and imitation skills of the children with ASD, prompting for a long-term study in our next steps.**

Keywords— autism spectrum disorder (ASD), symbolic play, social robots, NAO, educational program)

I. Introduction

During the last decade, the deployment of social robots in the education of children with neurodevelopmental disorders has attracted much research interest (e.g., interaction of children with Autism Spectrum Disorder (ASD) with the robot, improve social skills and emotional skills, role-playing skills). ASD is a neurodevelopmental disorder with deficits in communication and social skills, as well as stereotyped repetitive behaviours. Increase in ASD cases highlight the need to update educational practises and methods towards the integration of research robots into training and learning. Although social robots are quite new, there is a variety of robots designed and developed to affect children with special needs and provide a new perspective in education and learning.

This paper presents how Social Robots can assist in developing functional and symbolic play skills in children with low functioning ASD. We examine the hypothesis, and the level, in which children with ASD improve prerequisite skills (eye contact, attention and imitation) of symbolic play after the interaction with the social robot. A quality research study was conducted according to the Action Research Paradigm, in which we measured and evaluated the results of small-scale interventions. All experimentation took place in a Special Primary School for Children with Autism, for 3 months (Nov2020-Jan2021), in which five (5) low functioning and nonverbal students (2 girls and 3 boys, aged 7-10 years) took part.

For the experiments, we developed six (6) educational applications deployed for the humanoid NAO 6 robot (SoftBank Robotics), namely (1) *NAO presents itself*, (2) *Touch me*, (3) *NAO-NAO are you there?*, (4). *Let's cook*, (5) *Let's behave like the animals*, and (6) *Song and dance*. All applications were designed and developed in Softbank Choregraphe. Each student interacted with NAO robot, three times. Data collection accomplished through a camera -in compliance with GDPR rules[1]- and two observation grids, evaluating four (4) variables: (a) the duration of the eye contact (>2''), (b) the duration of the attention (>3''), (c) the frequency of imitation and (d) the level of engagement (Likert scale). Initial results demonstrate the positive impact on functional and pretend play skills children with ASD after the NAO-robot-based interventions, in line with [1].

This paper begins with a review of the literature regarding the humanoid social robot and the education of the children with ASD. Section II presents our research question and sub-question and describes the research methodology. The design and the implementation of the applications are presented in section III. Section IV describes evaluation and results, followed by conclusions, limitations, and the future work final section V.

II. Literature review

Play has been recognized by the United Nations High Commission for Human Rights as a right of every child and its vital role in children's development [2]. Symbolic and pretend play among children is connected with their physical, social, emotional, and cognitive development. Symbolic play is one of the four kinds of play according to Piaget [3] and it is characterized by the ability of children to represent an object that is not present or to pretend that an object has different functionalities from its real. It appears at the age of two, but first signs can be detected during the new-born age [4].

ASD is the most common neurodevelopmental disorder. Children with ASD have impairment in social skills and in communication and repetitive behaviours (DSM-5, 2013). Additionally, they play differently. Deficits in this area are related to their entire development. It has been observed that children with ASD, have difficulties to acquire new play skills, through observation, social engagement, or verbal communication like their peers [5]. Towards their intrinsic motivation, a safe, familiar, structured environment, involving favourite themes, is needed. To demystify their way of thinking, it is important to observe the perception, the experience, the coding, and the role of emotion at these children. Their pretend play is poor without elements of

[1] EUR-Lex - 32016R0679 - EN - EUR-Lex: http://data.europa.eu/eli/reg/2016/679/oj

imagination. They are limited to the real word and its materials (e.g themselves or a doll) [5]. Lack in eye contact, in paying attention and in imitation skills, reduce the abilities and the engagement in upper level of play.

Social robots (i.e., Softbank NAO [6], Pepper, Kaspar [7], JIBO [8], PARO [9]) have been designed to interact with people, helping them socially and improve their quality of life. Additionally, social robots are widely used as educational or therapeutic tools [10]. They can look like a human or an animal. According to Saleh et al. [1] NAO robot constitutes the most frequently used robot. NAO is a 58 cm tall, humanoid robot (Fig. 1). It has 25 degrees of freedom to move around. Through its seven (7) sensors in the head, the hands and feet, four (4) speakers and microphones, and its two (2) cameras, it can interact with humans as well as the environment. Additionally, NAO can recognize and speak 20 languages and it is programmable [6].

Social robots can become an important tool, offering new possibilities in the educational process for people with ASD [11,12]. First time in 1976, Sylvia Weir and Ricky Emanuel used robots as an educational and therapeutic tool to improve communication skills of a seven-year-old boy with ASD [11]. Simut et al. [13] used PROBO social robot to investigate the differences of interaction of children with ASD with the robot, involving a human partner during functional play. They ask to prepare a fruit salad according to PROBO's or human partner's preferences. They found that children had more often eye contact with PROBO than with human partner.

Scassellati et al. [14] investigated the effects in ASD children's engagement and joint attention, after a long-term home-based intervention with the social robot Jibo. Twelve (12) children with ASD, aged 6 to 12 years, interacted with their caregiver and the robot for one month, during 30-minutes sessions every day. After the intervention the children improved joint attention skills without the existence of the robot.

Regarding NAO robot, Robaczewski et al. [15] provide strong evidence that the robot holds the capacity to improve social skills (imitation, eye contact, interaction, attention), and emotional skills (recognition of emotions, empathy) of students with ASD. Barnes et al. [16] examined comparatively children with ASD and typically developing children, interacting with a NAO social robot or a human partner during a musical dance game "Dance Freeze Game". They found that children with ASD paid more attention and had greater engagement interacting with NAO.

Alnajjar et al. [17] used a combination of a simple autonomous assessment system for the attention and a semi-autonomous interactive system for the children's interests to improve attention and interaction skills. They showed that this dynamic interaction system increased the engagement and attention of the children with ASD.

Though limited, there are few research studies reporting on the deployment of social robots to improve symbolic play. So et al. [18] investigated how to develop role-playing skills in children with autism (4 to 6 years) using social robots. After nine weeks sessions with two NAO robots dramatizing three simple scenarios, students with ASD appear increase of spontaneous participation in symbolic play conditions. Additionally, most research studies are about improvement in separated skills. Regarding symbolic play, in most studies participants are children with high functioning ASD.

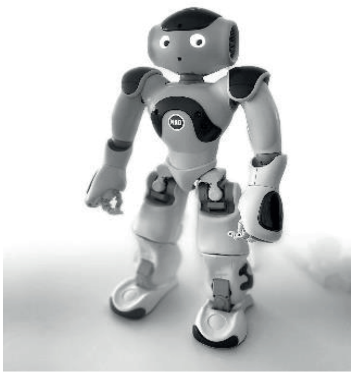

Fig. 1. NAO humanoid

However, symbolic play is very important for every child's development and understanding of the word. Towards, we designed robot-based interventions using NAO, to enhance these skills to children with ASD, studying the added pedagogical value of the robot.

III. Methods and Materials

The aim of the present study was to explore the correlation that can be developed among the Symbolic Play, ASD and the Social Robots. Specifically, we examined if a humanoid social robot (NAO, 6th generation, SoftBank Robotics) can develop or improve functional play and pretending play skills in low functional students with ASD. This main research question requires experimentation to respond to the following requirements:

1. Did students making eye contact and how long?
2. Are they attentive to what the robot is doing and how long?
3. Do they imitate robot's behaviour and how many times do they imitate the motion or the sound?
4. Do they engage in play with the robot and in which level?

To address our research questions, we conducted a pilot qualitive research with intervention on short scale. The research took place in a Special Elementary School for Children with Autism, during January 2021. Five students with ASD (2 girls and 3 boys) aged between seven and ten years old participated in this study. All students were nonverbal and low functioning according to C.A.R.S. scale [19].

We designed an educational scenario in compliance with the Greek Curriculum for Children with ASD and Bloom taxonomy. After the intervention the students would be able:

- To imitate NAO robot's movements.
- To imitate NAO robot's sounds.
- To match objects or images moving like NAO.
- To use their body to pretend that they are doing something in solitary play.
- To use daily objects or toys that are like real to pretend that they are doing something in solitary play.

- To pretend to be someone or something else, human or animal.
- To engage spontaneously or with added stimuli (prompts) in symbolic play or pretend play.

To measure the intervention impact, a pre/post-test was deployed. According to the educational scenario, each student played with the NAO robot three (3) times, in which we evaluated the following four measurements:

i. Eye contact (>2”) [12]
ii. Attention (>3”) [1]
iii. Imitation (Frequency) [1]
iv. Engagement (Likert scale) [12].

Data collection was applied using a camera and two observation grids measuring the four beforementioned variables. The duration of each activity was also measured. Eye contact requires looking at the head of NAO (fixation) for more than two (2) seconds [12]. Attention requires eye contact for more than three (3) seconds [1]. When a child imitates or tries to imitate moves and sounds of NAO, it is considered a successful imitation [1]. Engagement in play with NAO is measured by a 5-Likert, from intense noncompliance to intense engagement [12].

To program NAO we used Choregraphe v.2.8.6.23 [20], (Appendix 1). Choregraphe is simple and can be used for optical programming, even from novices. On the other hand, a professional developer can program it straight through PYTHON. Authors can combine different pre-programmed behaviors (walk, dance, turn, lie down, standup, reading sensors, speech synthesis, speech recognition, turning LEDS on and off) to create new ones according to user’s needs.

IV. Design & Implementation

The educational scenario included six (6) sequential activities that were designed in the form of diagram flows (see first layer in Appendix). The diagram flow was first for a virtual robot, and then it was applied in the real robot in the CoNSert Laboratory (University of West Attica) [21]. Application and evaluation took place in real school settings (Fig. 2).

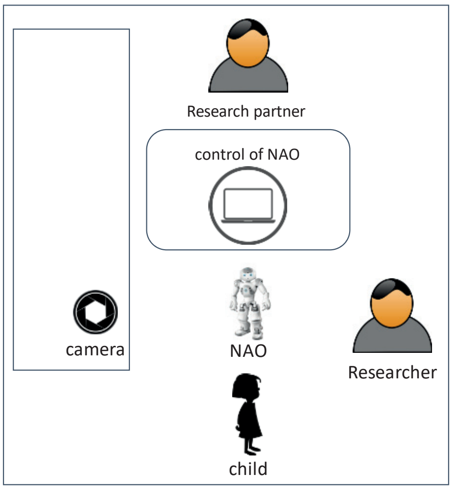

Fig. 2. Detail of main experiment area

The first two activities familiarize children with the new process and NAO. The 3rd, 4th, and 5th activities had a different level of symbolism. Last, there is the 6th (closing) activity, with a popular childish song (Table *I*).

Table I ACTIVITIES

No	Activity	Description	Symbolism Level*
1.	NAO presents itself	Introduces NAO to students, presenting its movements, sounds, speech and lights.	-
2.	Touch me	Brings students close to NAO by touching its head and hands, triggering a reaction from the robot	-
3.	NAO-NAO are you there?	Inspired by a Greek child’s play song. Real clothes were used as reference point and NAO pretends to wear them	1
4.	Let’s cook	NAO invites children to cook together using metaphors (e.g., cut string instead of spaghetti)	2
5.	Let’s behave like the animals	NAO presents of photo of an animal and pretends it, inviting the students to do so, imitating its movement and sounds.	3
6.	Song and dance	NAO is playing a popular child’s song and dancing	-

***Levels of Symbolism**
Level 1: Real objects as reference
Level 2: Fake objects
Level 3: Images instead of objects

V. Application & Results

At the evaluation phase, the students were prepared a week before the intervention, to reduce their level of stress. During pre-test, the baseline was assessed, while during post-test, we assessed the improvements in children functional and symbolic play. We kept records for each student (S1-S5) of duration, kind of play, and the level of engagement, (Leuven-Leaver’s scale [22]) (Table *II*).

Table II PRE- AND POST- TEST RECORDS

	Pre-Test		**Post-Test**	
	Kind of play	***Engagement***	***Kind of play***	***Engagement***
S1	sensory play	5	sensory play	5
	functional play	4	pretend play	3
	pretend play	3		
S2	sensory play	2	sensory play	5
			functional play	4
			pretend play	3
S3	sensory play	1	sensory play	5
			Constructive Play	5
			pretend play	2
S4	sensory play	5	pretend play	3
	functional play	3	early role play	5
	pretend play	4		
S5	sensory play	5	sensory play	5
	pretend play	4	pretend play	4

At the three NAO sessions we kept and analysed records of the four variables (refer to subsection III), that are coding as I1, I2, I3 and I4 respectively (Table *III*). Afterwards, we described the results per variable with diagrams, that show the value of each variable in every activity.

Table III RECORDS FOR EACH STUDENT

	Students and Indicators				
	S1	S2	S3	S4	S5
	Mean	Mean	Mean	Mean	Mean
C.A.R.S. score	45.0	46.0	48.5	32.0	33.0
I1 (%)	33.07	33.81	39.93	42.49	43.77
I2 (%)	32.89	34.32	38.36	41.57	48.05
I3	0	0	1	2	2
I4	3	3	1	3	4

Specifically:

I1. Eye contact: According to C.A.R.S. preliminary test, S4 and S5 avoid eye contact with adults, while S1, S2 and S3 need many frequent attempts to look someone. At NAO sessions all students look at NAO spontaneously at 38% of the total time corresponding to Simut et al. findings [13] (Chart *1*)

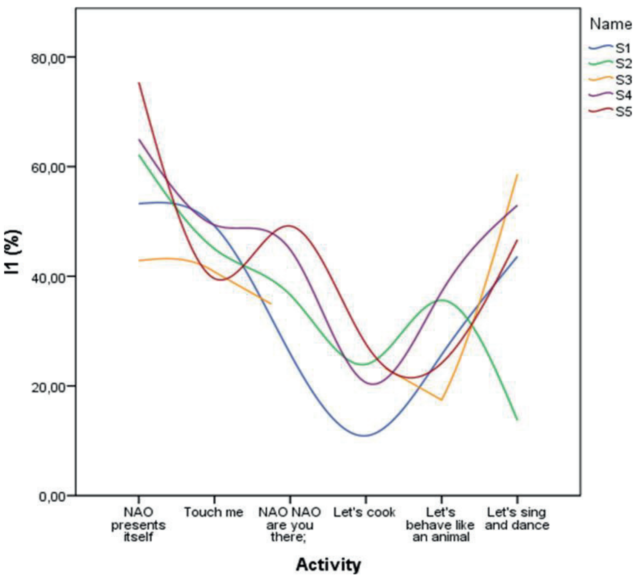

Chart 1. Eye contact in activities

I2. Attention: In our preliminary test, S1, S2, and S3 need intensive tries to pay attention. The other two, S4 and S5 show indifference and do not respond frequent to others. In attention, it is following eye contact pattern, during sessions. Levels of attention were high with mean 38,4% of the whole session time (Chart *2*) validating Pop et al. [14].

I3. Imitation: For S1, S2 and S3, imitation skill is characterized moderately abnormal, while for S4 and S5, mildly abnormal. In line with previous studies [16], all students imitated NAO's moves and sounds in the majority of records. In (Chart *3*), we cannot identify any pattern among students, but we can see that the imitations of high functioning students are more frequent than in low functioning students. The results depend on the severity of ASD.

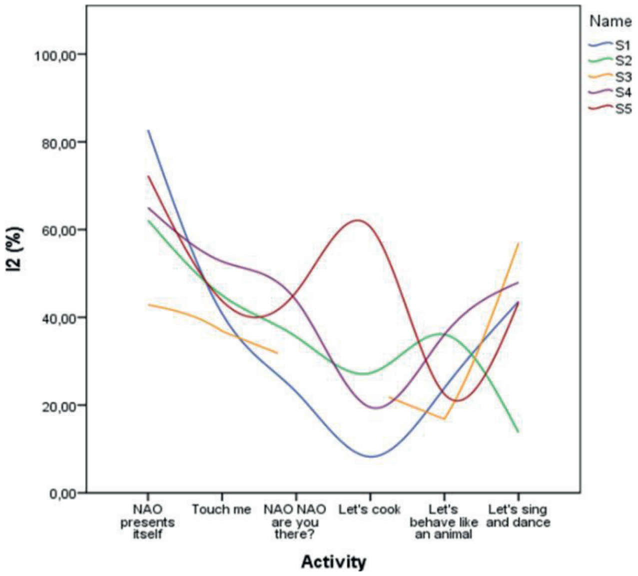

Chart 2 Attention in activities

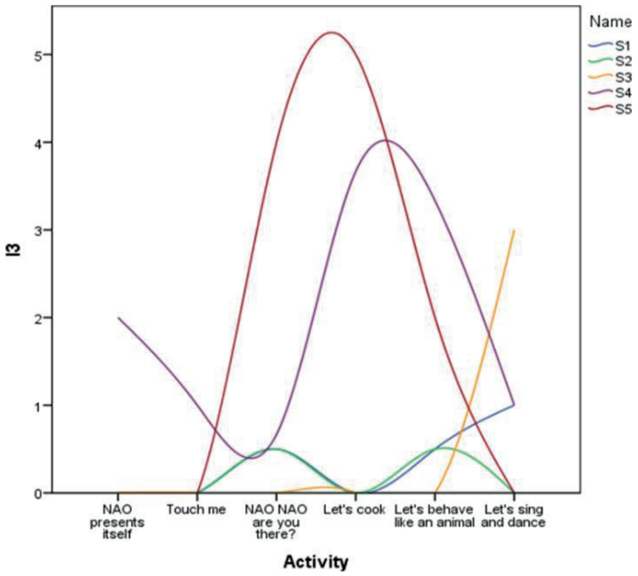

Chart 3. Imitation in activities

I4. Engagement: Children with ASD spend most of their time in non-social activities and in solitary play. The differences in results among students due to the severity of ASD, make clear that four students showed slight engagement (Chart *4*), while S3 show remarkable progress during the experiment.

Application and characteristics: Finally, it worth mentioning, children's interaction with NAO's sensors increases level of engagement. Activities with sounds and motion enhance eye contact and attention, as a result improve imitation's frequency although children require some guidance, most of the time.

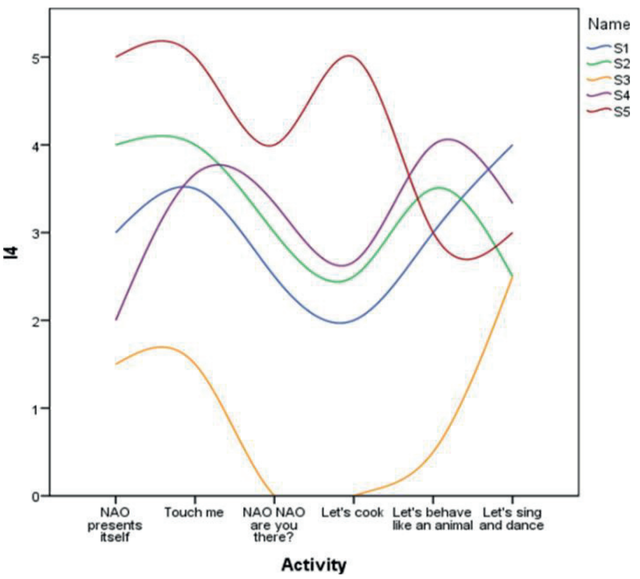

Chart 4. Engagement in activities

VI. Conclusions and Future steps

From our experiments we conclude that all students increase eye contact frequency, attention, imitation and engagement with NAO Robot. Moreover, post test showed that NAO robot improved and enriched children functional and symbolic play behavioural patterns. Activities that involved some kind of interaction increased engagement levels and activities with audio-motion combination increased eye contact and attention. Moreover, activities with familiar subjects increased imitation behavior. In addition, it is notable that low functioning children with ASD require some physical guidance, increased eye contact and attention.

On the other hand, our research studies are characterized by three main limitations resulting in difficulties in data collection: (1) the various technical problems of NAO robot and choreographe software, since frequent unexpected behaviours were noticed; (2) the small sample size; and (3) the experiments' duration. As a result, we need to extend our experiments to provide more safe results. Towards, we have obtained a new NAO robot, while all applications have been redesigned. Next steps include more scientific experimentation in larger sample size and a future validation study. Moreover, it is important to observe the impacts of NAO in functional play overall and compare the results of generalization with a human partner.

Acknowledgment

We would like to thank Mobile Technologies that provided NAO Robot for the pilot research, in the context of their collaboration with CoNSeRT.

References

[1] M. A. Saleh, F. A. Hanapiah, και H. Hashim, 'Robot applications for autism: a comprehensive review', *Disability and Rehabilitation: Assistive Technology*, pp. 1–23, July 2020, doi: 10.1080/17483107.2019.1685016.(accessed 24/05/2021)

[2] Convention on the Rights of the Child text _ UNICEF, (*accessed Dec 7, 2021)* at https://www.unicef.org/child-rights-convention/convention-text

[3] S. G. Garwood, 'Piaget and play: Translating theory into practice', *Topics in Early Childhood Special Education*, vol. 2, no. 3, pp. 1–13, Oct. 1982, doi: 10.1177/027112148200200305.

[4] P. J. Wolfberg, *Play and imagination in children with autism*, 2nd ed. New York : Overland Park, Kan: Teachers College Press ; AAPC/Autism Asperger Pub. Co, 2009.

[5] S. Powell and R. Jordan, Eds., "Rational for the approach" in *Autism and learning: a guide to good practice*, Classic ed. Abbingdon, Oxon ; New York: Routledge, 2012.

[6] SoftBank Robotics-Humanoid and programmable robots, (*accessed Dec 6, 2021)* at https://www.softbankrobotics.com/emea/en

[7] Kaspar the social robot _ Kaspar the social robot, (*accessed Dec 7, 2021)* at https://www.herts.ac.uk/kaspar/the-social-robot

[8] jibo _ Together for you, (*accessed Dec 7, 2021)* at https://jibo.com/

[9] PARO Therapeutic Robot, (*accessed Dec 7, 2021)* at http://www.parorobots.com/

[10] D. Feil-Seifer και M. J. Mataric, 'Socially Assistive Robotics', στο *9th International Conference on Rehabilitation Robotics, 2005. ICORR 2005.*, Chicago, IL, USA, 2005, pp. 465–468. doi: 10.1109/ICORR.2005.1501143.(accessed 11/10/2020)

[11] V. Kostrubiec και J. Kruck, 'Collaborative Research Project: Developing and Testing a Robot-Assisted Intervention for Children With Autism', *Front. Robot. AI*, τ. 7, p. 37, March 2020, doi: 10.3389/frobt.2020.00037. (accessed 24/05/2021)

[12] Pop, C.A., Pintea, S., Vanderborght, B., & David, D. O. (2014). Enhancing play skills, engagement and social skills in a play task in ASD children by using robot-based interventions. A pilot study Interaction Studies. Social Behaviour and Communication in Biological and Artificial Systems, vol. 15(2), pp. 292–320. https://doi.org/10.1075/is.15.2.14pop (accessed 19/10/2020)

[13] R. E. Simut, J. Vanderfaeillie, A. Peca, G. Van de Perre, και B. Vanderborght, 'Children with Autism Spectrum Disorders Make a Fruit Salad with Probo, the Social Robot: An Interaction Study', *J Autism Dev Disord*, vol. 46 (1), pp. 113–126, January 2016, doi: 10.1007/s10803-015-2556-9 (accessed 14/10/2020)

[14] B. Scassellati *κ.ά.*, 'Improving social skills in children with ASD using a long-term, in-home social robot', *Sci. Robot.*, vol 3, (21), p. eaat7544, August 2018, doi: 10.1126/scirobotics.aat7544. (accessed 16/11/2021)

[15] A. Robaczewski, J. Bouchard, K. Bouchard, και S. Gaboury, 'Socially Assistive Robots: The Specific Case of the NAO', *Int J of Soc Robotics*, June 2020, doi: 10.1007/s12369-020-00664-7. (accessed 24/05/2021)

[16] J. A. Barnes, C. H. Park, A. Howard, και M. Jeon, 'Child-Robot Interaction in a Musical Dance Game: An Exploratory Comparison Study between Typically Developing Children and Children with Autism', *International Journal of Human–Computer Interaction*, vol. 37(3), 249–266, February 2021, doi: 10.1080/10447318.2020.1819667. (accessed 16/11/2021)

[17] F. Alnajjar, M. Cappuccio, A. Renawi, O. Mubin, και C. K. Loo, 'Personalized Robot Interventions for Autistic Children: An Automated Methodology for Attention Assessment', *Int J of Soc Robotics*, 13(1), 67–82, February 2021, doi: 10.1007/s12369-020-00639-8. (accessed 16/11/2021)

[18] W.-C. So *et al.*., 'A Robot-Based Play-Drama Intervention May Improve the Joint Attention and Functional Play Behaviors of Chinese-Speaking Preschoolers with Autism Spectrum Disorder: A Pilot Study', *J Autism Dev Disord*, vol. 50(2), pp. 467–481, February 2020, doi: 10.1007/s10803-019-04270-z.(accessed 24/05/2021)

[19] J. S. Kreutzer, J. DeLuca, and B. Caplan, Eds., *Encyclopedia of Clinical Neuropsychology*. New York, NY: Springer New York, 2011. doi: 10.1007/978-0-387-79948-3.

[20] Home _ SoftBank Robotics Developer Center, (*accessed Dec 7, 2021)* at https://developer.softbankrobotics.com/

[21] CoNSeRT – CoMPUTER NETWORKS & SeRVICES RESEARCH TEAM LAB, (*accessed Dec 7, 2021)* at https://consert.eee.uniwa.gr/

[22] F., Leavers, Well-being and Involvement in Care Settings. A Process-oriented Self-evaluation Instrument, Kind & Gezin & Research Centre for Experientel Education,2005, https://www.kindengezin.be/img/sics-ziko-manual.pdf (accessed 022/06/2020)

Appendix I Screenshot of the application 1st level diagram flow