NAO Robot as tool operator in therapy sessions with mentally impaired individuals

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Abstract— **In the last decades a new generation of robots has emerged, the Socially Assistive Robots, which has been used to aid human beings. Recently, several studies were made using NAO Robot in cognitive therapy sessions. Therefore, this work presents a study that aims to understand if the humanoid robot NAO can improve the eye gaze and joint attention of young adults with mental impairments. The intervention involved two different approaches, a Game-Based Approach and a Robot-Based Approach. A greater involvement and attention was point out during the second approach**

I. INTRODUCTION

Everyday new technologies are emerging that can be applied to endless means in the healthcare sector. Robotics is no exception and it is one of these emerging areas, that has great potential when applied to this sector. SAR (Socially Assistive Robots) are a rising star when concerning the healthcare in general and the mental healthcare in particular [17]. SAR has recently emerged as a key robotics research area [15], that brings together a broad spectrum of research, including robotics, medicine, social and cognitive sciences and neuroscience, among others [31]. SARs' aims to create a close and effective interaction with human users, for the purpose of giving assistance and achieving measurable progress in convalescence, rehabilitation, learning, etc. [33]. Which means that SAR can be widely characterized by the task that the robot is assisting with, its target population and the behavioral illusion and appearance that it can diffuse [11]. Further, SAR have been sorted into two operational groups, service and companion robots. Service robots are tasked with aiding activities, whether companion robots are generally associated with improving the psychological status and overall well-being of the users [1]. Therefore, SARs' have worked as caregivers, such as in therapy aids for children dealing with grief and loss, as well as, social mediators for children with Autism Spectrum Disorders (ASD) or as companions in nursing and elementary schools [11].

Consequently, many are the developments that are being made in the application of social robots in mental healthcare scenarios, regarding, not only, the elderly population, but also, children and young adults with mental disorders, in order to either improve psycho-social outcomes, to prevent cognitive decline, or to improve the patient capabilities and lifetime [9, 27]. Though, the need to understand how Human Robot Interaction (HRI) actually occurs and how robots influence people's emotions during this interaction is still a reality that requires our full attention [9].

Individuals with mental impairments are often characterized by not being able of living by themselves and independently, due to delays in the development of social, communicative and motor skills, as well as, their inability to follow orders. Further, they often exhibit attention deficits and are stubborn by nature. For those reasons, mentally impaired individuals live with care providers or in specialized group homes. However, even when insert in these specialized group homes mentally impaired individuals often show resistant behavior and tantrums whenever they do not want to do specific tasks.

Therefore, the aim of this work is, not only, to understand how the HRI processes actually works, with people with cognitive impairments, but also to test the application of the humanoid robot NAO in the therapies sessions of the study group and verify if this kind of HRI really impacted the improvement of their cognitive skills, development of eye gaze and joint attention. The robot is used, in order to understand if their resistant behavior and tantrums can be decreased when in session with NAO compared to a normal session without the robot.

The robot adopted in the pilot study was NAO due to its simplified, hence accessible, human-like features. Moreover, the goal of this study is to prove that the interaction via humanoid improves the joint attention and eye gaze of mental impaired young adults beyond people with ASD.

This article is structured as follow. Section I, introduces the robotics advances and the need to use it the mental healthcare, as well as, the research focus. Section II describes the existing related work. Section III describes the methodology, including the robot and software used, as well as, the overall setup and participants. Two different approaches are described. Results are presented and discussed in section IV. The article ends with some conclusions and recommendations for future work, in section V.

II. RELATED WORK

With the arrival of humanoids many were the sectors that started to used them as an asset, and NAO has been used as a multitask tool in several areas including as an educational or a therapeutic tool, ever since. Hence, in the medical field, robots have been increasingly used in autism diagnosis treatment [30], for the treatment of cerebral palsy [24] and even in the field of orthopedics with surgery-assisting technology. As such, many are the articles that provide us with a broad range of successful practical application of humanoid robot NAO in these areas. NAO is typically used to aid autistic children to learn basic skills that are naturally learned by the typical children and to help them improving their behavior, their social and communication skills, which includes joint attention and eye gaze [25, 26]. A compilation of these studies is exposed as follow.

The authors in the paper [26] presented a pilot experiment protocol where children with ASD were exposed to NAO, in order to understand which was the initial response and behavior of children with ASD in this kind of environment. They concluded that during the robot interaction the children-robot eye contact was higher, that with a teacher during regular classes. Moreover, NAO's simple appearance compared to actual humans is able to act as a pull-factor to ignite the child's interest to sustain interaction. Similarly, the work developed by [21] presents modules that encourage children with autism to improve their social and communication skills through a game-based approach. Further, [20] designed and evaluated a robot-based intervention protocol, where NAO was used to deliver behavioral training mechanism for children with ASD, in order to teach those skills to the children to improve their social and communication skills. This study revealed that the majority of the participants showed behavioral response improvement and that they were, also able to engage in learned skills during human-human follow-up sessions.

Moreover, the authors of [13] developed and tested an embodied mirroring setup for therapy sessions with ASD children that aimed to improve their motor and social skills, validating the study as a milestone to take in account in future work. According to [34] there are "50 apps available within ASKNAO, which is an easy-to-use platform that can be used by therapist and parents as a tool to help them deliver educational syllabus to the children with autism". The authors in [25] show in their article that 4 out of the 5 children exhibited a decrease of autistic behavior when the robot is executing HRI modules in a single session, indicating that NAO is able to attract the children's attention, keep them engaged and hence give positive impact in the children's communication behavior. On the other hand, [3] presents proposal to recognize autism symptoms based on a preschoolers' play with NAO ('Touch me' and 'Dance with me'), here ASK NAO was inspiration for the applications developed for this project. [22] used NAO to physically show emotional poses and conduct a simple guessing game with autistic children.

In [35], the authors aimed to examine how 20 children learned complex social rules from NAO through distrust and deception games. In [2] it is described a Low-Cost Autonomous Attention Assessment System where it was possible to assess autistic individuals' attention during robot intervention. Hence, [12] assessed the improvement of Eye-Gaze Attention of Children with High Functioning Autism after sessions playing NAO Spy games. Moreover, [10] have used a novel deep learning neural network architecture to automatically estimate the level of concentration of children with ASD by their visual attention on the robot during therapy sessions. Further, in the first scenario described in [6], an approach to develop joint attention during autism therapy was developed.

Several others robots have been used for these purpose, as well. For instance, the author of [5] used a robot prototype, CHARLIE, in a new robot-assisted intervention with children with ASD, which indicated significant improvements in spontaneous utterances, social interaction, joint attention and requesting behaviors of the participants. Moreover, [32] used a mobile robot with a special costume and a monitor to display multimedia contents to serve as mediator in session with ASD children, proving that the robot stimulated the social skills in 4/5 of the ASD children. In addition, authors in [7] showed that after recurrent sessions with the robot KASPER, children with ASD started to directed their eye gaze increasingly less towards KASPAR and more time at the experimenter, which suggests that KASPAR successfully functioned as social mediator.

On the other hand, NAO as, also, been applied as an aid for mentally impaired people. As described in [19], Dr. Ayanna Howard and her team are developing a system that would allow NAO to provide children with developmental disabilities, such as cerebral palsy, with in-home therapy sessions. [24] created several scenarios in order to understand if children with CP would imitate NAO's movements.

III. Methods

The aim of this study was to test if a methodology, where a humanoid is the vehicle used to introduce concepts to a mentally impaired group of young adults, can help them keep their focus and joint attention during a specific task. It was, also, our objective to understand if mentally impair young adults can focus better in the task when the activity is led by the humanoid.

A. Materials

NAO is a humanoid robot, but even though NAO possess the human like characteristics that put it in this category it has simpler features when compared to real humans. NAO is a multi-functional, autonomous, programmable robot that can walk, speak, and even dance [16, 23]. It was developed by Aldebaran Robotics, a French robotics company, as a research platform in the field of HRI in 2006 [4, 16]. However, it was only in 2008 that this humanoid robot was introduced to the market [26]. By 2015 Aldebaran Robotics was acquired by SoftBank Group and rebranded it as SoftBank Robotics [16]. Nowadays, NAO is in its 6th generation and it is widely used in both research and as a teaching aid in science, technology, engineering and math (STEM) [4, 28]. It can provide friendly user programming through code or voice and facial recognition competences, in order to support HRI architecture during interventions [23, 25]. NAO is 57cm in height, weighs 4.3Kg and has 25 DOF from its head to its feet, moreover each joint is equipped with position sensors [13, 14, 16, 28]. Thus, NAO has nine tactile sensors, two 2D cameras, four directional microphones, two sonars, Bluetooth, Ethernet and Wi-Fi connectivity, motors, a software running on built-in Naoqi Linux based operating system and it is powered by a LiPo [13, 14, 16, 29].

B. Participants

The study groups of this work involved twelve young adults with mental impairments, of an IPSS from the north of Portugal. An IPSS is a non-profit institution establish by private parties. In this specific case, the Institution receives young adults with more than sixteen years old that are unable to proceed with regular education, in order to promote new opportunities for these citizens.

In Table 1, it is possible to see that 8 out of the 12 participants were women and the other 4 were men, the age ranges from 23 to 60 years old. Moreover, it is possible to see that the know diagnoses of the study groups' members are really heterogeneous, including mental retardation, schizophrenia, cerebral palsy and down syndrome, though every one of these individuals have learning and attention deficits in common.

The participants were chosen by the Institution Teachers, after them being informed about the study characteristics and methodology, according to the users' capabilities and limitations.

An authorization was given to the researchers that able them to perform the study in premises of the institution, as well as, to allow the participants to engage in the study.

Table 1. Demographic information of participants

Participant	Gender	Age	Diagnoses
A1	Female	53	Schizophrenia.
A2	Female	60	Severe mental retardation.
A3	Male	23	Cerebral palsy.
B1	Female	51	Mental retardation and motor disability.
B2	Female	29	Cognitive retardation.
B3	Female	23	Down Syndrome.
C1	Male	59	Development delay and left spastic hemiparesis.
C2	Male	45	Motor deficit, cognitive retardation and language disorder.
C3	Male	53	Mild mental retardation and sequels from an ischemic stroke.
D1	Female	59	Cognitive retardation.
D2	Female	31	Cerebral palsy.
D3	Female	43	Cognitive retardation.

C. Experimental Design

The proposed study was conducted, in order to validate if NAO can be considered a more engaging tool than an ordinary game or task, by observing for how long the group members would keep their attention focused in the activity. Furthermore, the main objective was to understand if the participants would decrease their resistance behavior during determinate tasks when the session was conducted by NAO over when it was conducted by the operator, as well as, if their eye gaze and joint attention would improve under the circumstances mentioned above.

The experimental setup, which can be observed in Figure 1, consists on a simple table where NAO would seat on one side and the computer with a video camera on the other. Both objects should be in front of the study group. The operator and the guardian were placed on both sides of the computer and the robot, respectively. Note that NAO's head and the computer screen were placed at participants' eye height, in order to be easier for them to see NAO's eyes and the computer screen. Both NAO and the computer are at a certain distance from the group members for a security measure.

The experimental setup was composed by just one area (interaction) instead of two (interaction and operator), once that the objective was to perform the two approaches in a row. Moreover, the operator presence on the interaction was not considered to be a problem with the group's members.

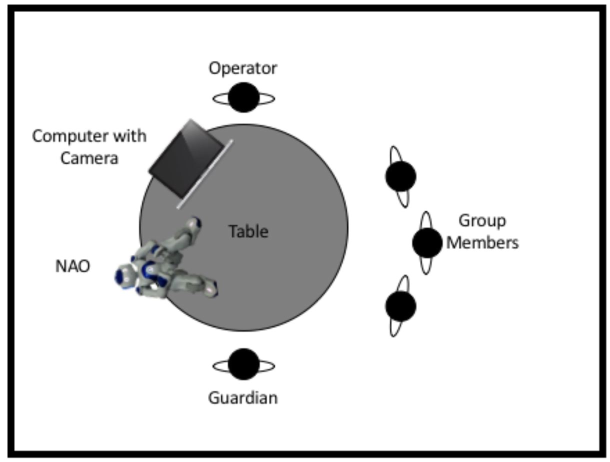

Figure 1. Experimental Setup

The intervention involved two different approaches, a Game-Based Approach and a Robot-Based Approach.

The study involved a first introduction, where the operator introduces herself to the group and briefly points out what is going to happen. Afterwards, the Robot-Based Approach starts with the operator introducing NAO as a robot and soon after NAO starts its introduction. After the group finished the Robot-Based Approach, the operator does the transition to the Game-Based Approach starting by explaining the computer game to the group, then the operator conducts the game, asking the questions and helping manipulate the computer. In Figure 2, it is possible to see the flowchart that describes the events mentioned above.

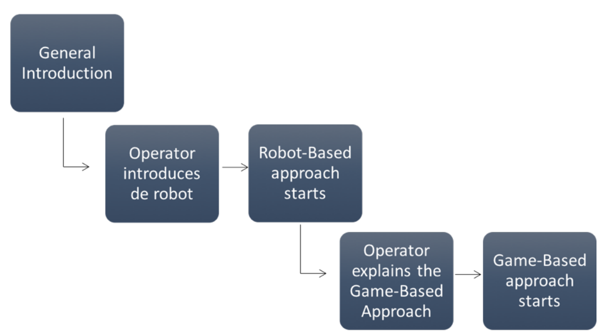

Figure 2. Flowchart of the events for both approaches

So, two sessions were carried (S1 and S2), with three groups each and every group was submitted to the two different approaches during their session time. It is important to remember that, in both sessions, all the groups that were involved in the study case were stipulated by the Institution Teachers, according to the users' capabilities and limitations. Thus, all the groups had three participants at a time, however their health conditions vary from person to person. The session S1, was during a morning period and had three different study groups (GA, GB and GC). While session S2 was performed during an evening period. In the session S2 three different study groups participated in the experiment, however just one of them was considered viable to the study due to a recording problem (GD).

The video recording of each session allowed us to after the sessions, by human analysis, count the amount of times that each individual looked away from the activity. Note that, we considered when an individual looked away was distracted at that moment, so whenever the participant looked away he was considered to be distracted.

Thus, it was necessary to separate these distractions in three different groups "Total", "Self-Distracted" and "No Interaction". The "Total" stands for the total amount of times that each participant looked away. On the other hand, in the "Self-Distracted" category is only accounted for the times that the individual looked away whenever there were no distracting agents. Moreover, the "No Interaction" group refers to the amount of times where the group members were distracted and there was no interaction from the robot at that moment. This last group it was only considered in the Robot-Based Approach, once that the interaction with the robot happen there.

D. *Robot-Based Approach*

In the Robot-Based Approach the robot has to execute behaviors that are send by the operator in loco and in real time, which means, that the operator had to follow a Wizard of Oz (WoZ) approach, instead of using the modules offered for communicative dialogue in *Choregraphe*. Note that the four directional microphones, localized in NAO's head, are the sensors that allow NAO to "capture" sounds. Though, when using Choregraphe NAO needs to be instructed to search for sounds at specific moments, in order to allow its built-in algorithms to translate the sound into in answer recognizable to NAO. Which means, that the programmer has to code the words that NAO needs to search for when it is capturing sounds. Moreover, the robot will only be looking for those words in a specific time window. Additionally, if the diction issues, as well as, introvert personalities of the participants are taken in account, the probability of such error happen are much higher. Thus the WoZ approach was chosen, once that it was established that the speech recognition behaviour does not work properly, either when the room is too crowded or noisy or even if the person answering do not answer at the proper moment [6, 18], which leads to the robot expecting another answer or for loops in the code.

The WoZ method implies a human operator that helps coping with the difficulties of the real environments, once it supplements the weaknesses of the robot software [6, 18]. Thus, this method can, also, be advantageous in experiments where the aim is to work with more than one robot at the same time, where the same operator can control the robots used [18]. Therefore, a WoZ approach was safer to use, not only due to the reasons mentioned above, but because this method is already well documented for persons with ASD and it has been proven to work properly in such cases.

So, several "Say" and a "Motion" boxes were programmed beforehand using *Choregraphe*, as demonstrated in Figure 3, in order to be manipulated by the operator at the innervation sessions. Nevertheless, the objective of the script was to induce the participants to think that NAO was interacting with them autonomously.

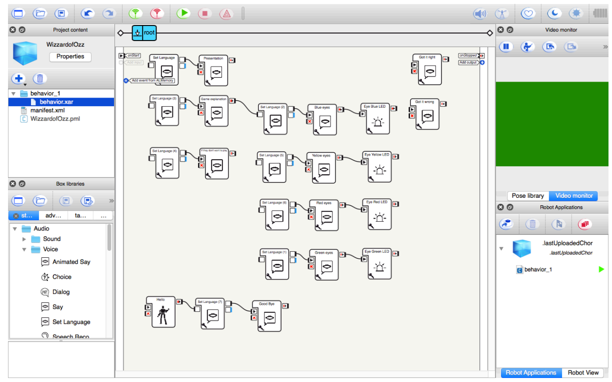

Figure 3. Modules algorithm in *Choregraphe*

Basically, the script tells NAO to start by introducing himself to the participants and to explain the activity to them. Afterwards, NAO is induced to ask the participants if they want to play a game and if they agree, NAO starts it. In this game, NAO's eyes color change and the study group has to say what color did they changed to. After they give an answer, NAO will give them feedback about it. If the participants were right, the robot will go forward to another color, and on the other hand, if they were incorrect NAO will show them the same color again. This cycle repeats until all the colors selected, which in this case are four (yellow, blue, green and red), are covered. Hence, the goal of this approach was to realize if therapy sessions where NAO is used to improve cognitive skills of mentally impaired young adults can be used in individuals with other mental retardation beyond ASD.

E. *Game-Based Approach*

In the Game-Based Approach the operator used a Power Point presentation with a two-level game.

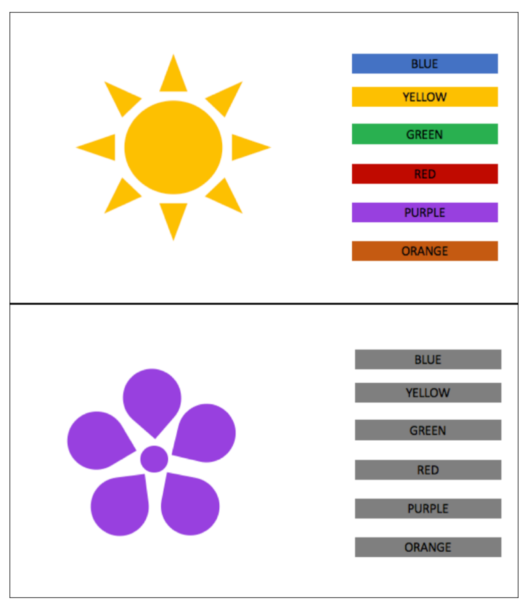

Figure 4. Examples of both levels of the Game-Based Approach

As it is possible to observe in Figure 4, both levels have a one-color drawing and a multiple choice, in order to the participants tell which color was the drawing of.

The difference between the two levels, is that in the first one the multiple-choice rectangle has both a color, the color name written on it, as it is possible to see in the upper image of Figure 4. Moreover, an audio can be played, saying the color name out loud, whenever the mouse is hover an option. On the other hand, in the second level of the Game-Based Approach, the multiple-choice rectangle is grey and has the color name written on the option, as it is represented in the lower image of Figure 4. The audio option can also be played.

The audio was added, in both levels, for the eventually of a participant cannot read. Moreover, the Game-Based Approach has two levels, unlike what happens in the Robot-Based Approach, in order to be as appealing and engaging as possible.

IV. Results

When comparing the times, in total, that an individual looked away in both approaches, seven out of twelve participants were more distracted during the Game-Based Approach, than during the Robot-Based Approach, as it is possible to see in Figure 6. Additionally, just one of the participants was more distracted during the Robot-Based Approach. The remaining four participants looked away the same amount of time during both approaches.

In the color scheme of Table 2, it is possible to observe that the green modules represent the approach where the number of times that a certain individual looked away were smaller when compared with the other approach. Hence, the red modules represent the approach were the number of times that an individual looked away was higher. Moreover, whenever the values were equal in both approaches, for the same individual, the modules were colored yellow. For instance, the participants A1, A2, B2, B3, C1, C2 and D1 looked away more times during the Game-Based Approach when compared to the Robot-Based Approach. Therefore, the modules of the Game-Based Approach are red and the ones of the Robot-Based Approach are green. On the other hand, if we take in consideration participant A3, it is possible to observe that the opposite has happen and consequently the respective module of the Game-Based Approach is green, while the module of the Robot-Based Approach is red.

Table 2. Number of times that each individual looked away

	Game-Based Approach	Robot-Based Approach
Participants	Total of distractions	Total of distractions
A1	2	0
A2	20	12
A3	3	4
B1	0	0
B2	3	1
B3	37	22
C1	11	3
C2	4	3
C3	3	3
D1	18	9
D2	19	19
D3	12	12

Moreover, the modules of both approach in the cases of individuals B1, C3, D2 and D3 are yellow, once that those participants looked away the same amount of times in both approaches.

However, if we analyze the data on Figure 5 and we compare the number of times that an individual is "Self-distracted" in the Game-Based Approach, with the number of times that an individual was distracted during NAO's intervention ("Total"-"No Interaction"), in the Robot-Based Approach, it is possible to verify that eleven out of twelve of the participants were more focused on the Robot-Based Approach.

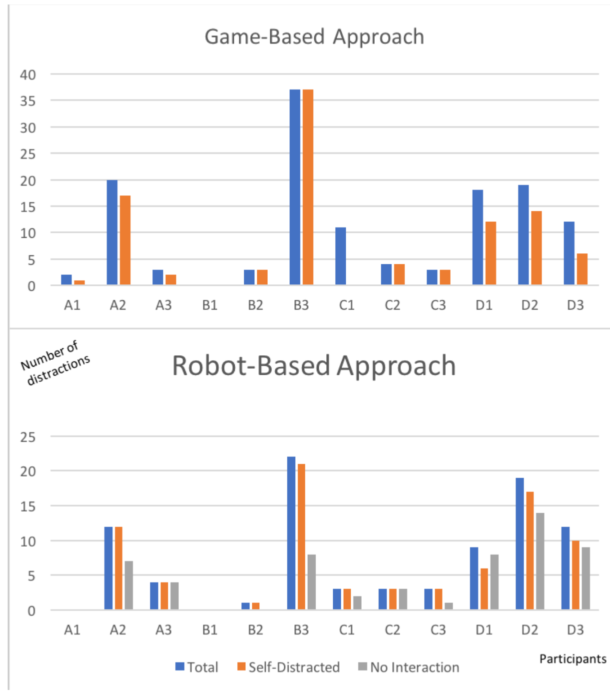

Figure 5. Number of times that each individual looked away in each category

Moreover, the participant B1 did not look away, even once on either approaches. This participant was part of the group where the Robot-Based Approach was longer than the Game-Based Approach, being focused in the NAO's activity for twice the time. Therefore, it was also interesting to understand that even in the GB group, the participants either were more focused in the Robot-Based Approach, looking away less than half of the times during the intervention, or kept their focus in both activities. Hence, in the case of participant B3 it was, also, possible to verify that the individual kept looking away for longer periods in the Game-Based Approach when compared to the look away periods in the Robot-Based Approach. Furthermore, it was possible to observed that when NAO talked, the participant would always be focused on NAO. Hence, several were the participants that treated NAO as a social being, either by trying to talk to it or physically interacting with it.

V. Conclusion

By reviewing the state of art in the Robot-assisted therapy field it is possible to acknowledge that many has already been made with ASD patients, essentially with children and using

NAO as a therapy tool. Though, there is still a major lacuna between the Robotic scientific research field and to a potential clinical application, specifically when it comes to mentally retarded individuals. However, these individuals are considered to be a group of interest to potential clinical application of Robot-assisted therapy.

It is important to acknowledge that mentally impaired individuals have often attention deficit and are stubborn, which normally contributes to their inability to follow orders or even to live with different social standards.

Yet, with this study it was possible to conclude that the results from both sessions with the mentally impaired young adults were actually positive, once that it was possible to prove that the participants kept their focus and improved their joint attention during the Robot-Based Approach. It was possible to access the efficiency of NAO as a teaching tool, that is able to capture the group members' attention, once that during the Robot-Based Approach was notorious an increase in the joint attention and eye gaze of the participants. Moreover, it was also verified that the interaction of the study group does in fact change, when in presence of the humanoid NAO, paying, in overall, more attention during NAO's approach than during the computer game one.

Therefore, NAO was capable of improving the group's resistance behavior and their attention. Thus, we can consider it as a considerably efficient tool that should be applied in institutions, however the cost of the Robot and its programming maintenance is still a major concern for this kind of Institutions, mostly in countries like Portugal, where there is still little Robot-assisted therapy happening. The creation of standard protocols could be an interesting asset to be consider.

Although this study has presented itself as an overall success, there were some throwback during sessions that should be considered in future work. So, even though it was adopted a WoZ approach due to the malfunctions that were expected to arise during sessions, with the study group, still some issues happened. There were internet connection problems, which interfered with the loading of the commands to NAO, which took longer than expected during the group sessions. That created a time slot where the activity was frozen, i.e., without interaction from NAO. For that reason, a more autonomous approach should be preferred in the future. Another question, that also, emerged during the group sessions was the instability of the intensity and duration of the NAO's eye LEDs when it changed eye's colors, during the Robot-Based Approach. Which could also be due to the internet connection issues.

Therefore, in future approaches it should be considered if there is a need to change to a new software, once it is fundamental to decrease the loading time of the commands, as well as, to increase the robot's autonomy throughout the hence of the robot's speech recognition. Also, the stability of the eye LEDs intensity and duration should be one other focus of intervention. In addition, internet connection should be studied at the local of intervention beforehand. On one hand, this will solve all the concerns described above, but on the other, it will increase the knowledge needed to program the robot, which means that the therapists will always need someone specialized in programming, which with *Choregraphe* could be avoided if the therapists were properly trained.

During the group sessions, the operator felt the need to ask individual questions to better understand the participants dynamic in both approaches. Therefore, in future approaches it would be more advantageous to only have an individual at a time instead of groups. Furthermore, in future studies, it would be interesting not only to add another level in the Game-Based Approach, as suggested by one of the teachers at the Institution. But also, to add another level on the Robot-Based Approach, where NAO could physically interact with the participants. Further, it would also be interesting to do a gymnastic class taught only by NAO to truly understand that it could conduct a tutoring class on its own. This approach could also be compared to a traditional gymnastic class tutored by a teacher, to understand in which of the approaches the study group would be more engaged in the activity. Last but not least, in order to understand if the joint attention of the participants is improved with NAO, in future approaches the study should be done in continuous during several months, with session once to twice a week.

Therefore, and in conclusion, this study proves to be useful once that showed that NAO can be used as a tool for applications in therapies with young adults with mental impairments and future work should be conducted to better support the claim.

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