NAO Robot applied to the development of cognitive skills.

By

Ana Maria da Cruz Freire

Supervisor: António Luís Gomes Valente

Supervisor: Vítor Manuel de Jesus Filipe

Dissertation submitted in
UNIVERSITY OF TRÁS-OS-MONTES AND ALTO DOURO
to obtain the
MASTER
in Biomedical Engineering, in accordance with the law
DR – I série–A, Decreto-Lei n.º 74/2006 de 24 de Março e no
Regulamento de Estudos Pós-Graduados da UTAD
DR, 2.ª série – Deliberação n.º 2391/2007

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"Any intelligent fool can make things bigger and more complex... It takes a touch of genius – and a lot of courage to move in the opposite direction."

Albert Einstein (1879 – 1955)

"Change will not come if we wait for some other person or some other time. We are the ones we've been waiting for. We are the change that we seek."

Barack Obama(1961 – Today)

"You cannot hope to build a better world without improving the individuals. To that end, each of us must work for his own improvement and, at the same time, share a general responsibility for all humanity, our particular duty being to aid those to whom we think we can be most useful."

Marie Curie(1867 – 1934)

UNIVERSIDADE OF TRÁS-OS-MONTES AND ALTO DOURO

Master in Biomedical Engineering

The Jury members advise the University of Trás-os-Montes and Alto Douro the acceptance of the dissertation named "**NAO Robot applied to the development of cognitive skills.**" carried out by **Ana Maria da Cruz Freire** to partial fulfill the requirements of the **Master** Degree.

June 2020

President: **Luís José Calçada Torres Pereira**,
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Aplicação do Robot NAO ao desenvolvimento de capacidades cognitivas.

Ana Maria da Cruz Freire

Submetido na Universidade de Trás-os-Montes e Alto Douro
para o preenchimento dos requisitos parciais para obtenção do grau de
Mestre em Engenharia Biomédica

Resumo — A robótica, desde os seus primórdios, foi considerada como uma área concentrada principalmente em problemas de controlo (Jayawardena et al., 2016), no entanto, durante a última década (van den Berghe et al., 2018), a robótica mudou de paradigma, focando-se mais na automatização das nossas atividades quotidianas (Tapus et al., 2019).

O que posteriormente, levou ao surgimento de uma nova geração de robots, os robots sociais. Estes subdividem-se, principalmente, em duas categorias, os humanoides e os animaloides. Contudo, neste estudo irei apenas focar-me nos humanoides (robots com características físicas semelhantes às de um ser humano e capazes de interação (Kim et al., 2018)). No entanto, ainda é preciso compreender melhor como a HRI funciona, ou seja, como é que a interação com os robots influencia as nossas emoções durante essa interação, especialmente no caso dos humanoides, por apresentarem características físicas idênticas às nossas (Desideri et al., 2019).

Assim, pretendo compreender, não só como é que estes processos funcionam no caso de pessoas com deficiência mental, mas também, em testar a aplicação do NAO nas suas sessões de terapia, por forma a verificar se a HRI realmente afeta as suas capacidades cognitivas, bem com o seu desenvolvimento.

Nos últimos anos o NAO tem vindo a ser usado, principalmente, como um robot social em testes com crianças com ASD, tendo já provado, em diversas ocasiões, ser uma ferramenta útil para o seu desenvolvimento pessoal. Consequentemente, o objetivo deste trabalho passa, por provar se o NAO pode ou não ser usado para ajudar jovens com deficiência mental a manter o seu foco de atenção centrado numa determinada atividade.

Desta forma, foi adotada uma abordagem WoZ, em vez de usar os módulos oferecidos para o diálogo comunicativo do *Choreograhe*. Este método implica um operador, que manuseia o robot através de um computador em tempo real, que permite lidar com as dificuldades técnicas que possam surgir em ambiente real e não controlado, já que este método permite complementar o software nas suas falhas (Kanda and Ishiguro, 2013; Cao et al., 2018).
Palavras Chave: Desenvolvimento Cognitivo, Humanoide NAO, Interação Humano-Robot.

NAO Robot applied to the development of cognitive skills.

Ana Maria da Cruz Freire

Submitted to the University of Trás-os-Montes and Alto Douro
in partial fulfillment of the requirements for the degree of the
Master in Biomedical Engineering

Abstract — Robotics was a technological area that was mainly focused on control problems (Jayawardena et al., 2016), however over the past decade (van den Berghe et al., 2018), robotics has shifted its paradigm, as well as, its course of development, in order to automatize our everyday environments (Tapus et al., 2019).
Therefore, a new generation of robots has emerged. Social robots are mostly categorized in two types of forms, humanoids and animaloids. Although in this study, I will only focus on humanoids, which are robots with physical features similar to humans and capable of interaction (Kim et al., 2018).
Nevertheless, there are still a need to understand how HRI works and how social robots influence people's emotions during this interaction, especially when it comes to humanoids (Desideri et al., 2019). Therefore, my aim is to not only to understand how these processes actually work with people with mental impairment, but also, to actually test the application of a humanoid robot, NAO, in therapy sessions, in order to verify if this kind of HRI can have a real impact on their improvement on their cognitive skills and development.
For the past few years, NAO has been mostly use as a social robot in trials with children with ASD, and has proven to be a useful tool in their personal development. Consequently, the aim of this study is to prove if NAO can be used to enhance joint attention in mentally impairments young adults.
Furthermore, it was decided to follow a WoZ approach, instead of using the modules offered for communicative dialogue in *Choreograh*. This method implies a human operator that helps coping with the difficulties of the real environments, once it supplements the weaknesses of the robot software (Kanda and Ishiguro, 2013; Cao et al., 2018).

Key Words: Cognitive Development, NAO Robot, Human-Robot Interaction.

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UTAD, Ana Maria da Cruz Freire
Vila Real, 19 de Dezembro de 2019

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UTAD, Ana Maria da Cruz Freire

Vila Real, 19 of December of 2019

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Glossary, Acronym and Abbreviations

Glossary

List of Acronyms

Acronym	Expansion
AR	*Assistive Robotics*
ASD	Autism Spectrum Disorders
cHRI	*Cognitive and Social HRI*
cm	*Centimeters*
CP	*Cerebral Palsy*
DOF	*Degrees of Freedom*
HRI	*Human Robot Interaction*
IQ	*Intelligence Quotient*
LiPo	*Lithium Polymer*
pHRI	*Physical HRI*
SAR	*Socially Assistive Robotics*
SIR	*Socially Intelligent Robotics*

Acronym	Expansion
Kg	*Kilograms*
WoZ	*Wizard of Oz*

1 Introduction

Robotics was considered to be a technological area that was mainly focused on control problems (Jayawardena et al., 2016), however due to the rapidly developments over the past decade (van den Berghe et al., 2018) and to the change in people's needs, robotics, as many other fields, has changed its paradigm, as well as, its course of development. Therefore, robot's nature is shifting from the factories to our everyday environments (Tapus et al., 2019). This led to the need to supply robots with human like skills (Tapus et al., 2019), such as, the capability to observe, interpret and expect something from an action, which can helped robots to "gradually evolved from one-function automatons to intelligent systems of versatile features" (Savela et al., 2018). Which allowed the robots to interact with people (Tapus et al., 2019) and to serve a wide range of areas (Borovac, 2012), such as the medical or the educational field (Savela et al., 2018; van den Berghe et al., 2018; Desideri et al., 2019). The same has happen with humanoid robots, once that its purpose is to operate in environment closer to humans (Borovac, 2012).

Therefore, some new concepts have emerged through time in robotics, due to its constantly shifting, such as SIR, AR and SAR. On one hand, SIR aimed to create robots capable of exhibiting natural-appearing social cues and capable of interaction

(Tapus et al., 2007; Feil-Seifer and Mataric, 2005). On the other hand, AR can be stated as the area of robotics which intends to aid or support a human user (Feil-Seifer and Mataric, 2005). Consequently, SAR brings together a broad spectrum of research including robotics, medicine, social and cognitive sciences, and neuroscience, among others (Tapus et al., 2007). It can be easily defined as the intersection area of AR and SIR (Feil-Seifer and Mataric, 2005) that can enhance the quality of life of the user (Tapus et al., 2007). Though, SAR aims to improve the assistance to human users through social rather than physical interaction (Tapus et al., 2007; Feil-Seifer and Mataric, 2005). Thus, it should be taken in consideration that HRI through SAR is a new interdisciplinary concept in the robotics field (Tapus et al., 2007), that in order to be achieved requires the interaction between multidisciplinary teams (Jayawardena et al., 2016).

Social robots are mostly categorized in two types of forms, humanoids and animaloids. This forms were adopted once that their shape is known to be crucial when social robots interact and communicate with humans (Campa, 2016). On one hand, a humanoid is a robot with physical features similar to humans (arms, legs, face, etc.), which means that humanoids are robots with human like appearance and mainly capable of interaction (Kim et al., 2018). Many studies and researchers have already proposed that humanoids are able to provide care with proper programming through assisting health providers. Humanoids can be used passively, like a tool to achieve a mean, or as an active being, being themselves the care providers (Kim et al., 2018). On the other hand, animaloids are robots with animal like features and also capable of interaction with humans.

The healthcare field is also facing great demands from the modern society. This is, not only, because of the technological developments, but also, due to the many modern problems that our society is now facing. Namely, the exponential growth and aging of the worldwide population, which has forced this sector to innovate and provide new ways to deliver better and more specialized healthcare. Moreover, people's standards and expectation of the healthcare sector are higher and higher every day. Further, there is lack of material, as well as, of human resources, that caused healthcare providers to look elsewhere for a solution for these problems, i.e., in robotics (Jayawardena et al., 2016; Delerue and Correia, 2018). Consequently, mental healthcare is considered one of the areas where robots will bring drastic changes (Sim and Loo, 2015). Even though robotics is already emerging as a tool to assist healthcare, it is still a priority to assure robots acceptance in society, as well as, its safety hazards (Savela et al., 2018; Desideri et al., 2019).

1.1 Motivation

The Biomedical Engineering field is in the border between the actuation of engineering and healthcare, therefore and in my opinion, it is important, as well as, our duty to enrich and help the later through engineering. This can be achieved through the massive changes suffered in both fields in the past few years. Furthermore, every day 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 the healthcare sector. SAR is a rising star when concerning the healthcare in general and to mental healthcare in particular (Desideri et al., 2019). 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 (Desideri et al., 2019; Sim and Loo, 2015).

Though, the need to understand how HRI actually occurs and how robots influence people's emotions during this interaction is still a reality that requires our full attention (Desideri et al., 2019). Therefore, the aim of this study is, not only, to understand how this processes actually works with people with cognitive impairments, but also, to actually test the application of a humanoid robot, NAO, in the therapies sessions of my study group and verify if this kinds of HRI really impacted on the improvement of their cognitive skills, development and joint attention.

1.2 Overview of the Research

The human brain, normally, prefers human to human interactions and does not respond emotionally to non-human artefacts (Kanda and Ishiguro, 2013). Although, when we talk about human-like artefacts, as humanoids, which are capable of interaction and are similar in features to humans that is not entirely true. Moreover, it is known that physical embodiment of a social agent increases its social presence, contributing to positive social responses from the person interacting with that agent (Lee et al., 2006). Therefore, it is expected that by using humanoid robots, which are in-between toys and animate social beings' category, as social assistants it would be possible to enhance the capabilities of young adults with mental impairments, once that they may be more appealing to those artefacts, as they prove to be in studies with children with ASD.

For the past few years, many were the studies developed with NAO, and it was mostly use as a social robot in trials that proved that humanoids can improve social skills for children with ASD, as well as, joint attention. Thus, the aim of this work is to prove if NAO can be used to enhance cognitive skills and joint attention in mentally impairments young adults without ASD.

NAO is a friendly humanoid with 57cm in height, weighs 4.3Kg and has 25 DOF from its head to its feet. Moreover, it has nine tactile sensors, two 2D cameras, four directional microphones, two sonars, bluetooth-ethernet-wifi connectivity, motors, its software is running on built-in Naoqi Linux based operating system and it is powered by a LiPo Battery. NAO also has speech and face recognition systems (Softbank Robotics; Ismail et al., 2012; Geminiani et al., 2019; Joglekar and Kulkarni, 2018) and another important aspect beyond NAO's characteristics, is the degree of autonomy that it allows during sessions, which is what allows the interaction between the robot and the user to occur.

As mentioned, above, NAO has a speech recognition system and it was design to operate on its own. However, this feature often fails in noisy environments, due to sound capture errors. Moreover, diction issues, as well as, introvert personalities can lead to slower answers, that can make the sound capture difficult. Therefore, it was decided to follow a WoZ approach, which allowed the operator to control all the speech and movements of the robot at a certain distance, making the study group believe that they are actually interacting with the humanoid alone.

This study, was divided in two approaches, a Game-Based Approach and a Robot-Based Approach, in order to understand in each one would the participants of the study group pay more attention to the activities.

In the Game-Based Approach, the young adults with mental impairments have to guess the colour of a form that is presented to them in a *Power Point* presentation. On the other hand, in the Robot-Based Approach the participants have to guess the colour of NAO's eyes. So, both approaches have the same goal, but use different platforms are used in order to engage the group members.

1.2.1 Research Questions and Goals

The main research goal is to assess if humanoid robot NAO can improve cognitive capabilities and joint attention time, of a mentally impaired group of young adults, when compared to a traditional game session with a new game. Therefore, those are my research goals:

Goal 1: To create a stimulating learning scenario with NAO.

Goal 2: To evaluate the efficiency of NAO as a teaching tool that is able to capture the group members' attention.

Moreover, I attend to answer the following research questions:

Question 1: Does the interaction of the study group changes with the humanoid in comparison with a computer game?

Question 2: How does NAO influence eye gaze and joint attention time of the study group during sections?

The resulting hypothesis are proposed:

Hypothesis 1: The study group perform better when in session with NAO.

Hypothesis 2: The study group improved their joint attention during the Robot-Based Approach when compared to the Game-Based Approach.

1.2.2 Methodological Considerations

Mentally impaired people are often characterized by not being capable of living independently because of their delay in the development of social, communicative and motor skills, as well as, their inability to follow orders. Further, they often exhibit attention deficit and are stubborn by nature. For those reasons, normally, mentally impaired people live with care providers or in specialized group homes.

Therefore, according to the research questions and goals, the aim of this research is to prove that is possible to transfer methodologies used in ASD cases to improve joint attention and captivity to other impairments.

In this study, it was used NAO and a WoZ approach due to the reasons mentioned above.

The scenarios design was based not only in literature, but also based on the teacher experience with the study group.

1.2.3 Ethical Considerations

The study group used in this research involved young adults with mental impairments. This research was submitted to the Ethics Committee of the University, once it was mandatory, and the following issues were taken in account:

Protocols: The Institution were the research was developed gave sign permission, via email, that allowed me to use their premises.

Parental consent: The young adults' parents or tutors signed an informed consent in which they allowed them to participate in the research.

Privacy: As protocoled in the parental consent, the personal data of the participants is enclosed and all the private information collected during the session is confidential Anonymity was guaranteed at all times.

1.3 Overview of Thesis Content

Chapter 2 presents a background knowledge on the Evolution of Robotics thought history. Moreover, I did an extensive review on robotics. This chapter starts with the concept of Social Assistive Robotics and its advantages and disadvantages. It is, also discussed the factors involved in HRI. Later on, in this chapter a brief definition of humanoid robots is made, followed by a full description of the NAO Robot applications.

Chapter 3 presents a literature review on mental impairment by explaining the differences between people diagnosed with the several forms of mental impairment.

Chapter 4 focuses on describing NAO and the software used, *Choregraphe*, as well as, the application of the approaches used to test the performance of the study group.

On **Chapter 5**, not only, the ethic consideration that were taken in account were exposed, but also the description of the participants and the pilot study was made.

On **Chapter 6** it is not only possible to contemplate the result analysis from both scenarios, but also the discussion of those results.

Chapter 7 pulls conclusions out of the results from the study group behaviour during both sessions. It also has an overlook of the future work.

2 Literature Review on Robotics

Since the beginning of times that the human body as served as an inspiration for canvas (Goswami and Vadakkepat, 2019; Siciliano and Khatib, 2016), as such, the desire to create machines that are human-like in appearance, as well as, in intelligent strated to emerged (Goswami and Vadakkepat, 2019; Siciliano and Khatib, 2016).

This constant dream lead science fiction to created models of human-like robots throughout the time, which has seriously influenced everybody's opinion, when it comes to the shape, form and appearance of the humanoid robots (Goswami and Vadakkepat, 2019).

Robotics started to emerge in the middle of the twentieth century and it was first defined as the science and technology of robots (Goswami and Vadakkepat, 2019). Robotics than started by revolutionize the industry sector, and by the late 1970s, robots were firstly introduced to the production lines (Kanda and Ishiguro, 2013; Goswami and Vadakkepat, 2019). These industrial robots were developed based in two main streams, navigation and manipulation, that are fundamental for their main purpose (Kanda and Ishiguro, 2013). On one hand, navigation is the main function of autonomous mobile robots that allow them to acquire an environmental model, in order to plan their trajectory from point A to point B. On the other hand, manipulation is the main function of the arms of the robot.

Later, in the 1980s, the definition of robotics was change to the science that studies the intelligent connection between perception and action (Goswami and Vadakkepat, 2019). Moreover, in the early 90's started to appear human-like and animal-like robots that aimed to interact with people in their every-day life environment. Therefore, interaction emerged as a key factor for the development of these interactive robots, which is assumed to be the main difference between the industrial robots and the SAR's (Kanda and Ishiguro, 2013).

By the beginning of the new millennium, the robotic field went through major transformations and rapidly expanded to the human world challenges, with the development of a human-centred and life-like robotics approaches (Goswami and Vadakkepat, 2019; Jung and Yoo, 2014). Which were expected to develop robots capable of social interaction with people, in order to safely and dependably cohabit with humans in homes, workplaces, and communities, providing support in a wide range of services (Goswami and Vadakkepat, 2019; Jung and Yoo, 2014).

However, to today's date, there are still major costs associated to the acquisitions of human-like robots, which is the main issue in the way of integrate them in our daily lives. Though, humanoids are beginning to win us over, an even if they are still out of range for most people, their integration in specialized facilities is highly achievable (Jung and Yoo, 2014).

2.1 Socially Assistive Robotics

As mentioned before Robotics as made a long way since automatized factories and its new challenges are centred in the human interaction, rather in control problems (Tapus et al., 2019). Therefore, now-a-days the aim of Robotics is to understand how to make robots close to human responses, in order to develop new features that could be applied in several domains, such as, education and healthcare (van den Berghe et al., 2018). Which bring us to the beginning of SAR's.

SAR can be defined as the intersection of AR and SIR (Sekmen and Challa, 2013; VÉLEZ and FERREIRO, 2014). Therefore, it is important to clarify these two concepts.

On one hand, SIR is defined as an autonomous or semi-autonomous robot capable of natural interaction and communication with humans following the behavioural norms expected by us (VÉLEZ and FERREIRO, 2014; Sekmen and Challa, 2013; van den Berghe et al., 2018; Campa, 2016). Hence, in these cases it is important to develop robots that can meet or address some social needs in real time (VÉLEZ and FERREIRO, 2014), such as, understand human activities, dynamics, and the intentions behind their behaviours, as well as, to include verbal and nonverbal communication (actions, gestures, body postures, facial emotions, and proxemics) (Sekmen and Challa, 2013; Tapus et al., 2019; Campa, 2016). In fact, social robots are normally humanoids or animaloids, once that its appearance it is extremely important to the success of its HRI (Campa, 2016). Moreover, AR implies that the robots are able to assist humans in their activities (VÉLEZ and FERREIRO, 2014). Consequently, SAR has recently emerged as a key robotics research area, (Jayawardena et al., 2016) that brings together a broader spectrum of research including robotics, medicine, social and cognitive sciences, and neuroscience, among others (Tapus et al., 2007). SAR's main aim is to create close and effective interaction with human users for the purpose of giving assistance and achieving measurable progress in convalescence, rehabilitation, learning, etc. (VÉLEZ and FERREIRO, 2014). Which means that SAR can be widely characterized by the task that the robot is assisting with, its target population and the behavioural illusion and appearance that it can diffuse (Feil-Seifer and Mataric, 2005).

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 its users (Abdi et al., 2018). Therefore, SAR 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 or as companions in nursing homes and elementary schools

(Feil-Seifer and Mataric, 2005). So, it is really important that SAR systems engage the user effectively and be responsive to the needs and requirements of user but, also, of the caretakers (Feil-Seifer and Mataric, 2005).

2.2 SAR's Advantages and Disadvantages

Robots, and in specific humanoids and animaloids, are presume to have a couple of advantages when compared to other forms of technology and traditional therapies.

Firstly, robots are more likely to be anthropomorphize by both children and adults, i.e., that they are more likely to be perceived as a normal play roller, once they can be programmed to take the roll of a teacher, peer or friend, rather than a machine (van den Berghe et al., 2018). Therefore, humanoids are, not only, more helpful and credible than animated characters, but also, more pleasing to interact with. In other words, SAR allows a more natural interaction, where the user can interact with the real-life physical environment (van den Berghe et al., 2018).

Even though, SAR's advantages are clear, there are major challenges still to unscramble. Therefore, there are still multiple complex conflicts that present themselves as difficulties to SAR (Feil-Seifer and Mataric, 2005; van den Berghe et al., 2018). The robot acceptance, not only, by the user, but also by the healthcare providers and professionals is one of the biggest challenges of SAR, once that proof of its efficiency is still lacking and scepticism is a remaining reality.

2.3 Human-Robot Interaction

As already mention, the rapid development made in recent years allowed to investigate HRI more deeply and away from factory settings, once that now a day's robots can be seen all over shopping malls, train stations, schools, streets and museums (Campa, 2016). Robots are more and more working closely alongside humans, finishing an era of technologically-driven towards a user-centred approach (Tapus et al., 2019).

Humans are social animals that are fundamentally emotional beings (Siciliano and Khatib, 2016). As mentioned, the human brain tends to prefer human to human interactions (Kanda and Ishiguro, 2013), once that is adapted to human characteristics, such as the sound of the human voice and the appearance of the human face and body motion (Siciliano and Khatib, 2016). Consequently, humans generally like to interact with one another and are more likely to work with each other (Goswami and Vadakkepat, 2019). Therefore, they are more probable to interact with artificial objects that have human-like characteristics, once that the human brain does not emotionally reacts to normal artificial objects, like computers or smartphones (Kanda and Ishiguro, 2013). Even though, human communication and social interaction are way more complex and it often relies on affective and emotive factors, such as emotive expressions (Siciliano and Khatib, 2016).

Moreover, during the past few years, many human-like robots have been developed and their ability to make human-like expressions has increased, has an attempt to foster peoples' social connection to them. Thus, it is expected that adding human-like cues to robots will aid humans to understand their gesture more intuitively and make the HRI more natural (Siciliano and Khatib, 2016), once that humans can even unconsciously behave as if they were communicating with peers (Kanda and Ishiguro, 2013). Nevertheless, it is really important that the humanoids' appearance and interface match its capabilities and the users' expectations (Siciliano and Khatib, 2016).

Even though HRI interest on the design, methodology, and theory of HRI has been growing (Tapus et al., 2019), HRI it is still a taboo and some people are more like to accept the interaction with robots than others. This is mostly due to a cultural influence that prefers human-like robots over machine-like robots when interaction is needed (Kanda and Ishiguro, 2013). As such, human kind tend to interact differently with a social robot than with autonomous mobile robots' due to the reasons mention above. Therefore, modern autonomous robots are generally viewed as tools used either on hazardous tasks or to perform tasks in remote environments. But, on the other hand, social robots are often seen as partners or peers, and can be involved in fields such as education, therapy, healthcare and research (Siciliano and Khatib, 2016). Thus, the development of social robots implies them to be as natural and intuitive for the general public as possible, as well as, to have the ability to recognize, understand, and predict the human behaviour (Siciliano and Khatib, 2016).

Like so, HRI has become a major area of concern as well as safety (Goswami and Vadakkepat, 2019). HRI is commonly divided into two major branches, in literature, cHRI and pHRI. On one hand, cHRI aims to study social and psychological properties of HRI, while pHRI, on the other hand, deals with the physical problems of interaction of the robot design and control (Jung and Yoo, 2014; Campa, 2016).

Though, there are some other key elements in order to HRI be considered successful.

Personality, which is considered to be the "pattern of collective character, behavioural, temperamental, emotional and mental traits of an individual that have consistency over time and situations", has been considered to be one of them (Tapus et al., 2007) and it can be created through a computational model that shall describes how the robot will answer environmental stimuli (VÉLEZ and FERREIRO, 2014).

Empathy is another important factor, mainly when referring to HRI in therapy cases, once that patients that receive genuine empathy tend to recover faster. However, is a difficult feature to achieve, once it will reinforce the human-robot relationship (Tapus et al., 2007).

Engagement is also a main component, once that establish and maintains collaborative and natural connection between the human and the robot. Therefore, in this area it is highly important both verbal and non-verbal communication, in order to engage interaction between the human and the robot and vice-versa (Tapus et al., 2007).

Finally, **adaptation** and **transfer** are also very significant. On one hand, adaptation allows the robot to learn from the user and adapts its capabilities to the user. On the other hand, transfer is considered to be the crucial metric to establish how successful the human-robot interaction was, once that in the majority of cases it is intended to enhance skill transfer to human-human interactions (Tapus et al., 2007).

2.4 Humanoid Robots

As previously mention, humanoids emerged as a vehicle to introduce robots in the real world, in order to connect them with humans and create a HRI (Kanda and Ishiguro, 2013). The development of humanoids capable of freely interact with humans in every-day scenarios is not that easy. However, the main aim is still to create human-like robots to be use in real services and not to develop perfectly function robots in a well-controlled situation (Kanda and Ishiguro, 2013; Goswami and Vadakkepat, 2019).

Humanoid robots resemble a human not only in appearance (Kim et al., 2018) (i.e. whit anthropomorphic physical shape (Shamsuddin et al., 2012a)) which is essential to HRI, but, they also have human like characteristics, such as, motion (harms, hands and legs), capability to sense throughout vision sensors and object learning and recognition (Joe Denny and D'Souza, 2016).

Furthermore, and even though humanoids have human-like features, they come in a variety of shapes and sizes. They are, also capable to collaborate with humans in their environments and with the same tools (Goswami and Vadakkepat, 2019). Therefore, this allow robots to perform several tasks in the human society, such as, assistant or communicative tool in entertainment, education and research either in our homes, offices, public spaces, healthcare scenarios, and disaster areas (Kanda and Ishiguro, 2013; Goswami and Vadakkepat, 2019). Moreover, humanoids can be an efficient tool as assistants of elderly individuals, as an avatar for telepresence or even as a tool to better understand humans (Goswami and Vadakkepat, 2019).

According to Siciliano and Khatib (2016); Joe Denny and D'Souza (2016); IEEE Spectrum (2019); American Honda Motor Co. Inc.; Passebon (2014), the evolution of humanoids robots development over time was documented in table 2.1.

Table 2.1 – The life of humanoids robots

Nº	Humanoid Robot Developed	Year	Manufacture
1	Leonardo's Robot	1495	Leonardo da Vinci
2	The Draughtsman, the Musicienne and the Writer	1774	Pierre Jacquet-Droz and Henri-Louis
3	Elekrto	1937	Westinghouse Eletric Corporate
4	Wabot 1	1973	Tokyo's Waseda University
5	Wabot 2	1980	Tokyo's Waseda University
6	WHL-11 i	1985	Hitachi Ltd
7	Cog	1993	MIT
8	Saika	1996	Developed at Tokyo University
9	Kismet	1998	MIT
10	ASIMO	2000	Honda
11	HRP-2	2002	Kawada Industries and AIST
12	Actroid	2003	Developed by Osaka University in conjunction with Kokoro Company Ltd.
13	QRIO	2003	SONY
14	Wakamaru	2003	Mitsubishi Heavy Industries
15	iCub	2004	RoboCub Consortium and IIT
16	Albert Hubo	2005	KAIST and Hanson Robotics
17	Kaspar	2005	University of Hertfordshire
18	Mahru	2005	Korea Institute of Science and Technology
19	Partner	2005	Toyota
20	CB2	2006	Osaka University
21	Geminoid HI	2006	Osaka University, ATR, and Kokoro
22	Herb	2006	University of Washington
23	NAO	2006	SoftBank (originally created by Aldebaran Robotics)
24	Kobian	2007	Waseda University
25	Kojiro	2007	Tokyo University

Continued on next page

Table 2.1 – *Continued from previous page*

Nº	Humanoid Robot Developed	Year	Manufacture
26	Twendy One	2007	Waseda University
27	Zeno	2007	Hanson Robotics
28	Rollin' Justin	2008	German Aerospace Center
29	Simon	2008	Georgia Tech
30	REEM-B	2008	PaL Robotics
31	PR1	2008	Stanford Personal Robotics Program
32	Tulip	2008	Delft University of Technology
33	ECCE	2009	The Robot Studio and ECCEROBOT Project
34	Flobi	2009	Bielefeld University
35	HRP-4C	2009	AIST
36	Hubo 2	2009	KAIST
37	KHR-3	2009	Kondo Kagaku
38	Rosie	2009	Technical University Munich
39	Petman	2009	Boston Dynamics
40	olivia	2009	A*STAR Social Robotics Lab
41	Octavia	2009	Naval Research Laboratory & Xitome Design
42	Pneuborn	2009	Osaka University
43	AILA	2010	DFKI Robotics Innovation Center
44	Bruno	2010	Hajime Research Institute and TU Darmstadt
45	Darwin-OP	2010	Robotis
46	Diego-san	2010	UC San Diego, Kokoro, and Hanson Robotics
47	Geminoid F	2010	Osaka University, ATR, and Kokoro
48	HRP-4C	2010	Kawada Industries and AIST
49	Surena	2010	University of Tehran
50	PR2	2010	Willow Garage
51	Robonaut 2	2010	NASA Johnson Space Center and GM
52	Telenoid	2010	ATR
53	CHARLI	2011	UCLA

Continued on next page

Table 2.1 – *Continued from previous page*

Nº	Humanoid Robot Developed	Year	Manufacture
54	Geminoid DK	2011	Aalborg University, Osaka University, Kokoro, and ATR
55	ASIMO 2nd Generation	2011	Honda
56	Kibo	2011	Korea Institute of Science and Technology
57	M1	2011	Meka Robotics
58	RoboThespian	2011	Engineered Arts
59	Waseda Flutist	2011	Tokios's Waseda University
60	AR-600	2012	Android Technologies
61	BHR-5	2012	Beijing Institute of Technology
62	Charlie	2012	DFKI Robotics Innovation Center
63	COMAN	2012	Italian Institute of Technology (IIT)
64	Dreamer	2012	UT Austin and Meka Robotics
65	FLASH	2012	Wroclaw University of Technology
66	Atlas	2013	Boston Dynamics and DARPA
67	Roboy	2013	University of Zurich's AI Lab
68	REEM-C	2013	PAL Robotics
69	Valkyrie	2013	NASA
70	Pepper	2014	SoftBank (originally created by Aldebaran Robotics)
71	Manav	2014	Laboratory of A-Set Training and Reasearch Institutes
72	DRC-Hubo+	2015	KAIST and Rainbow Robotics
73	Erica	2015	Osaka University, Kyoto University, and ATR
74	Atlas 2nd Generation	2016	Boston Dynamics
75	Emiew 3	2016	Hitachi
76	Sophia	2016	Hanson Robotics
77	Armar	2017	Karlsruhe Institute of Technology
78	TALOS	2017	PAL Robotics
79	HRP-5P	2018	AIST

Continued on next page

Table 2.1 – *Continued from previous page*

Nº	Humanoid Robot Developed	Year	Manufacture
80	qb SoftHand Research	2018	qb robotics
81	Mercury	2018	UT Austin, Meka Robotics, and Apptronik

Currently the list is way bigger and the most popular robots includes **Kurithe** home robot, **Sophia** (social humanoid), **Pepper** (research robot), **NAO** (autonomous robot), **Dinsow** (care robot), **iPal** (educational and care robot) and **ASIMO** (Joglekar and Kulkarni, 2018).

Several are the applications to robots now-a-days, as it is possible to see in table 2.1. Due to the increasing demand for more specialize and personal care, the healthcare system is one of the sectors that can benefit more from their use. Not only, because of the increase in the number of elderly, but also, due to the lack of enough health professional and materials to provide those types of care. Therefore, many were the purposes given to robots, including to the concept of SAR in the healthcare sector. However, introducing humanoids in our society can have significant implications reaching from economy to the working force and robot safety, as well as, dependability (Goswami and Vadakkepat, 2019).

2.5 NAO Robot Known Applications

With the arrival of humanoids, including NAO, many were the sectors that started to used them as an asset. One of those was the medical field, as already exposed, where robots have been increasingly used in autism diagnosis treatment (Taheri et al., 2015), for the treatment of cerebral palsy (Rahman et al., 2015) and even in the field of orthopaedics with surgery- assisting technology. Another application of a humanoid robots is in Education. As such, many are the articles that provide us with a broad range of successful practical application with several different humanoid robots, however in this section I will focus the achievements made with NAO.

In the current *state of art*, it is possible to acknowledge that NAO, as well as other robots, has been used as a multitask tool in several sectors including as the traditional robotic soccer (Vital et al., 2013). Though my focus will be on the ones regarding the HRI.

2.5.1 Autistic Children

Yet, NAO is typically used to aid autistic children to learn basic skills that are naturally learned by children without mental impairments and other conditions. Otherwise it would be difficult to ASD children to achieve those skills and to improve their social behaviour (Shamsuddin et al., 2012b,a). A compilation of these studies is exposed bellow.

The authors in the paper Shamsuddin et al. (2012b) presented a pilot experiment protocol where children with ASD were exposed to NAO, in order to understand which was the initial response and behaviour 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 Miskam et al. (2014a) presents modules that encourage children with autism to improve their social and communication skills through a game-based approach. These modules intend to increase eye contacts, imitation proficiency and correctness of their social and communicative behaviour. The abilities of NAO in voice and vision detection recognition are crucial, once that they will make the interaction between the robot and the children more attractive, which also helps them improve their social and communicative skills. Further, Mavadati et al. (2016) designed and evaluated a robot-based intervention protocol, where NAO was used to deliver behavioural training mechanism for children with ASD, in order to teach those skills to the children to improve their social and communication skills. Behavioural response as noticed to be improve after the intervention and their human- human follow-up sessions shown progress.

Moreover, Geminiani et al. (2019) 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. Also, according to Yussof et al. (2015) 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”. Shamsuddin et al. (2012a) shows in their article that 4 out of the 5 children exhibited a decrease of autistic behaviour 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 behaviour. On the other hand, Arent et al. (2019) presents proposal to recognize autism symptoms based on a pre-schoolers’ play with NAO (’Touch me’ and ‘Dance with me’), here ASK NAO was inspiration for the applications developed for this project. Miskam et al. (2014b) used NAO to physically show emotional poses and conduct a simple guessing game with autistic children. They developed nine different emotions through the use of Choregraphe and created an app in order to control NAO during the sessions with the children, sifting the robots’ mood in order them to guess what was wrong with the robot. In Zhang et al. (2019), the authors aimed to examine how 20 children, with and without ASD, aged between 5 to 8 years old learned complex social rules from NAO through distrust and deception games. The study show that social robots could facilitate the teaching of social rules to ASD children and showed that children’s perception of the robot plays an important role in their social learning. Thus, the authors Alnajjar et al. (2019) describe a Low-Cost Autonomous Attention Assessment System where it was possible to assess autistic individuals’ attention during robot intervention. In their study in the control part, the therapist was in the operator’s room controlling NAO, and in the experimental room the children were able to interact with NAO. Basically, they performed a

WoZ situation in order to assess their attention during the sessions. Ismail et al. (2011) proposed a face detection method for tracking the faces of children with Autism Spectrum Disorder in a robotic assistive therapy, in order to measure the concentration level of the children in social interaction and communication. Hence, Feng et al. (2013) assessed the improvement of Eye-Gaze Attention of Children with High Functioning Autism after sessions playing NAO Spy games. In this case, Face Detection Technique of Humanoid Robot NAO for Application in Robotic Assistive Therapy proposed a face detection method for tracking the faces of children with Autism Spectrum Disorder in a robotic assistive therapy in order to measure their concentration levels during social interaction and communication.

Moreover, Di Nuovo et al. (2018) 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, Cao et al. (2018), in the first scenario described an approach to develop joint attention during in autism therapy. The main aim of this approach was to increase step-by-step the complexity of the joint attention task, in order to understand if the participants could maintain their focus.

As mentioned, several others robots have been used for these purpose, as well, that performed studies with relevant information regarding joint attention and eye gaze. For instance, the author of Boccanfuso et al. (2017) 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. Hence, Valadão et al. (2016) 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 Costa Sandra (2013) 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.

2.5.2 Mental impairments

In the mental healthcare sector some achievements have been already been made, an a couple of examples are stated bellow. According to MathWorks (2018), 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. Once that they verify that NAO would keep them engaged during their therapy regime. Which is one of the most important features of the therapy sessions due to their repetitiveness and duration.

On the other hand, Rahman et al. (2015) created several scenarios in order to understand if children with CP would imitate NAO's movements. During the scenarios, NAO encourage the children to learn by imitation, in order to improve their sociability and motivation.

2.5.3 Elderly care

The elderly care is no exception to the application of the advances of SAR, an many are the investigator performing studies that would allow a more specialized care, without the need of human operators.

Joglekar and Kulkarni (2018), made a program where NAO could detect the user's mood and engage in a friendly conversation. They also acknowledge that humanoid robots are highly accepted among seniors. The authors in Vital et al. (2013) promote an extension to the NAO robot, RIA, which was not only built in order to work as a social interaction with the elderly. But also, to promote autonomous professional care through the analysis of health and environmental parameters. Therefore, RIA is an adapted NAO low-cost platform equipped with several sensors that can measure different parameters.

The authors, López Recio et al. (2013) created a program that allowed NAO to assist regular physiotherapy practices in order to take on the roles of the physiotherapist in modelling movements for the inpatients. The program was based in nine specific exercises defined by the physiotherapist of the facility. The workshop consisted in one-to-one sessions, where the patients could either be with their Physiotherapist as usual, the Physiotherapist could be assisted by a virtual version of NAO or the Physiotherapist uses NAO as a mirroring tool.

Another investigator, Leonel Crisóstomo from UTAD, used face and object recognition in order to give drugs to elderly people at the correct time to the correct person. He also created an app that allowed family to remotely move the robot and initiate a call with the elderly person that they wanted to talk to (INESC TEC, 2019; Watts On, 2019).

2.5.4 Differential Tool

On the other hand, there are many other sectors where NAO's abilities have been already exploited. Bertel and Hannibal (2015) investigated the role of NAO as a 'tool', 'social actor' or 'simulating medium' in learning designs in Danish primary schools. Al-Khalifa et al. (2017), describe how they developed a system called Mr. Saud that facilitates the educational process of using NAO. This interface was programmed to support fun leaning by providing an interface with many activities and games to test the student's understanding. All the interactions between the students and NAO are made through voice and touch. Moreover, the system enables the teacher to continuously review the student's progress and understanding via a web interface.

The authors, Vogt et al. (2019) design a series of seven lessons to teach English vocabulary to 5 to 6 years old native Dutch children as a foreign language using NAO as a (nearly) autonomous tutor. The sessions were mediated through a game played touch-screen tablet. The authors fund that children learn the target words, and that they can remember them better than children who participate in a control condition. Chandra et al. (2019) presented an autonomous educational system where NAO is used to enhance children's handwriting skills. The learning system is based on the learning-by-teaching approach on a one-to-one scenario, where a tutor-child assess the handwriting skills of the robot.

Moreover, Ahmad et al. (2017) conducted a study with children, to evaluate and measure which are the appropriate and effective adaptations portrayed NAO that sustains social engagement for an extended number of interactions during three different games. The authors showed that the type of adaptation that NAO does during each game has an effect on the social engagement in long-term children–robot interaction.

Further, the authors, Cao et al. (2018), in the third scenario made an approach where the user performs shoulder stretches and shoulder strengthening exercises from their physical exercise routine, by mimicking NAO's instruction through different exercises.

3 Literature Review on Mental Impairments

On this Chapter, an overall review of the pathologies diagnose to the study groups members is made. Note that even though some of the pathologies are not considered to be intellectual disabilities they will be discuss in this Chapter to. Moreover, it is important to acknowledge that intellectual disability and mental retardation are different designation for the same disability. In older literature we will find authors referring to it as mental retardation and, on the other hand, in newer editions the term changes for intellectual disability.

Furthermore, it is also important to understand two fundamental concepts that are at the central core of this study. The concepts of *eye gaze* and *joint attention* refer themselves to the way of looking steadily and intently at something or someone (Lexico, 2020) or to share a look with someone (American Psychological Association, 2018), respectively. Therefore, the main difference between the two is that the latest implies two or more individuals paying attention to each other and to a third object or event (American Psychological Association, 2018), while the first refers only to the object or event that an individual is focused on (Lexico, 2020). Moreover, *joint attention* is believed to play a fundamental role in the human development, once that infants can follow their parents' gaze and learn to imitate what their parents do (American Psychological Association, 2018).

Yet, intellectual disable individuals can have their ability to follow directions of *joint attention* intuitively compromised, and being trained to do so may be an important asset, not only, to learn new concepts but, also, to keep their focus during activities.

In this particular study, in the Robot-Based Approach NAO was used, not only, as the main event of focus, but also as the advisor to the group's eye gaze. On the other hand, in the Game-Based Approach a more traditional method were the operator is the party that engages the group's eye gaze to the computer game.

3.1 Intellectual Disability

The concept of intellectual disability refers to a disruption or incomplete development of the brain functions, with modification of both intellectual and adaptive functioning deficits in conceptual, social, and practical domains of the individual (American Psychiatric Association, 2013). Which are the faculties that regulates the overall level of intelligence, i.e. the cognitive, language, motor and social skills (Instituto de Apoio e Desenvolvimento (ITAD); Division of Mental Health and Preventiom of Substance Abuse, 1996).

In order to diagnose a patient with intellectual disability, the following three criteria must be met (American Psychiatric Association, 2013): **Criterion A** : Deficits in intellectual functions, such as reasoning, problem solving, planning, abstract thinking, judgment, academic learning, and learning from experience, have to be confirmed by both clinical assessment and individualized, standardized intelligence testing. **Criterion B** : Deficits in adaptive functioning that result in failure to meet developmental and socio-cultural standards for personal independence and social responsibility. Without ongoing support, the adaptive deficits limit functioning in one or more activities of daily life, such as communication, social participation, and independent living, across multiple environments, such as home, school, work, and community. This deficit prompts the failure to meet developmental and socio-cultural standards for personal independence and social responsibility. **Criterion C**: Onset of intellectual and adaptive deficits during the developmental period. Even though the various levels of severity are defined on the basis of adaptive functioning, and not IQ scores (American Psychiatric Association, 2013), must individuals show significantly subaverage general intellectual functions (IQ of 70 or less) associated to limitations described above (Instituto de Apoio e Desenvolvimento (ITAD)).

Thus, the onset of the limitations, already mentioned above, must occur before age 18, ie, during the development period of the individual (Instituto de Apoio e Desenvolvimento (ITAD); American Psychiatric Association, 2013). Moreover, the age and characteristic features at onset depend on the etiology and severity of brain dysfunction (American Psychiatric Association, 2013).

Intellectual disability has several causes that are mostly unknown, though some genetic and environmental factors are acknowledged to take a part and intellectual disability may be seen as a common pathway of countless pathological processes that affect the central nervous system (Instituto de Apoio e Desenvolvimento (ITAD); American Psychiatric Association, 2013).

It is important to understand that intelligence it is not a unitary characteristic and for that reason it should be assessed based on several different specific abilities (Division of Mental Health and Preventiom of Substance Abuse, 1996). Consequently, the assessment of intellectual level should be based on the available information, such as clinical findings, adaptive behaviour and psychometric test performance. Though for a more definitive diagnose the general intellectual functioning, which is defined by the IQ of someone, should be accessed. However, even though concepts such as general intellectual functioning that can be determined through well-establish test are used, children with intellectual disability are three to four times more susceptible to other mental disorders than in the general population which can difficult a thorough diagnose (Division of Mental Health and Preventiom of Substance Abuse, 1996).

There are four degrees of severity of intellectual disability that reflects the level of intellectual impairment of the patient (**mild**, **moderate**, **severe** and **profound**), moreover, it can also be found on the literature two other categories, the **unspecified severity intellectual disability** and **global development delay** (Instituto de Apoio e Desenvolvimento (ITAD); Division of Mental Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013).

In the **mild intellectual disability**, the general intellectual functioning should range from 50 to 69 (Instituto de Apoio e Desenvolvimento (ITAD); Division of Mental Health and Preventiom of Substance Abuse, 1996). In the majority of the cases until age 5 children with mild retardation are often non-distinguishable from children without any disorder (American Psychiatric Association, 2013). They normally develop social and communicative skills which allows them to have almost a fluent speech and hold a conversation, but can demonstrate immaturity in their social interactions. Though, they only can assimilate academic skills up to the sixth-grade, but special education programs can help them develop their skills and compensate their handicaps (Division of Mental Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013).

Once that mild intellectual disable adults usually achieve full independence, they are able to socialize and capable of work, with some supervision, guidance or assistance, in unskilled or semiskilled practical labour with some supervision(Division of Mental Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013). If living in a judge free environment, they usually are able to live successful in community(Division of Mental Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013).

In **moderate intellectual disability** the IQ tends to usually ranges from 35 to 49 (Division of Mental Health and Preventiom of Substance Abuse, 1996). People in this group can slowly acquire communication abilities in early childhood, however they have very little achievements in academic work and normally their abilities are equivalent to the second-grade, though some can learn basic reading, writing and mathematics skills, as well as, the perception of time and money (Division of Mental

Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013). Self-care and motor skills can also be retarded (Division of Mental Health and Preventiom of Substance Abuse, 1996). As adults, they are capable of do simple task-work, when careful structured and supervised, as well as, to engage in social activities and to travel independently in familiar places. Independent living is rarely achieved, but normally they adapt well to life in community (Division of Mental Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013).

In the **Severe intellectual disability** its intellectual functioning ranges from 20 to 34 in IQ-equivalent (Division of Mental Health and Preventiom of Substance Abuse, 1996). This segment is similar to the lower levels of achievement mentioned in the previous category, however severe metal retarded people have a much more marked degree of motor impairment or other deficits associated (Division of Mental Health and Preventiom of Substance Abuse, 1996). They rarely achieve communicative skills during childhood, though they can learn how to talk and elementary self-care abilities during school-age period (American Psychiatric Association, 2013). As adults, they can perform simple tasks with close supervision, and adapt well to life in community, either in group homes or with family, when with no other handicaps associated (American Psychiatric Association, 2013).

In **Profound intellectual disability** its IQ is under 20 (Division of Mental Health and Preventiom of Substance Abuse, 1996). Therefore most people in this group has very little ability to understand or comply to anything (Division of Mental Health and Preventiom of Substance Abuse, 1996). Most of them are immobile or have mobility restrictions, have incontinency and are capable of non-verbal communication. Though if in a highly structured environment some developments in self-care and communication can occur (Division of Mental Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013).

The **unspecified severity intellectual disability** category is meant to be used only when there is evidence of intellectual disability but the person could not be tested properly and there is no certainty in which category the patient should be assign to (Division of Mental Health and Preventiom of Substance Abuse, 1996), once that by means of locally available procedures is rendered difficult or impossible because of associated sensory or physical impairments, as in blindness or prelingual deafness; locomotor disability; or presence of severe problem behaviors or co-occurring mental disorder. This category should only be used in individuals over 5 years old and in exceptional circumstances and requires reassessment after a period of time (American Psychiatric Association, 2013).

The group of **global development delay** is reserved for individuals under the age of 5 years when the clinical severity level cannot be reliably assessed during early childhood. It should only be used when an individual fails to meet expected developmental milestones in several areas of intellectual functioning and when assessments through traditional methods is really difficult or impossible due to the early age of the children (Division of Mental Health and Preventiom of Substance Abuse, 1996; American Psychiatric Association, 2013).

3.2 Schizophrenia

The characteristic symptoms of Schizophrenia involve several criterions that are described bellow (American Psychiatric Association, 2013):

Criterion A: A mixture of characteristic signs and symptoms (both positive and negative). That can manifest as cognitive and emotional dysfunctions. No single symptom is pathognomonic of Schizophrenia (American Psychiatric Association, 2013).

The positive symptoms (Criteria A1-A4) appear to reflect an excess or distortion of normal functions of the individual. Criteria A1 to A4 include delusions, hallucinations, disorganized speech, and grossly disorganized or catatonic behaviour, respectively (American Psychiatric Association, 2013).

Delusions (Criterion A1) are erroneous beliefs that usually involve a misinterpretation of perceptions or experiences. If the delusions are judged to be bizarre, only this single symptom is needed to satisfy Criterion A for Schizophrenia. Hallucinations (Criterion A2) may occur in any sensory modality, however auditory hallucinations are the most common, which are define as voices that are perceived as distinct from the person's own thoughts. Disorganized thinking has been argued to be the single most important feature of Schizophrenia, thus their speech may be disorganized in a variety of ways, as well (Criterion A3). Grossly disorganized behaviour (Criterion A4) may manifest itself in a variety of ways and the Catatonic motor behaviours (Criterion A4) can include an obvious decrease in reactivity to the surroundings (American Psychiatric Association, 2013).

The Negative symptoms (Criterion A5) are account for a substantial degree of the morbidity associated with the disorder and include restrictions in the range and intensity of emotional expression (affective flattening), in the fluency and productivity of thought and speech (alogia), and in the initiation of goal-directed behaviour (avolition) (American Psychiatric Association, 2013).

Affective flattening is characterized by the person's face appearing immobile and unresponsive, with poor eye contact and reduced body language. Alogia is characterized by poverty of speech, manifesting itself with brief, laconic or empty replies. Avolition is the inability to initiate and persist in goal-directed activities. These negative symptoms are quite difficult to evaluate because they occur on a continuum with normality, are nonspecific way, and may be due to a variety of other factors (American Psychiatric Association, 2013).

Criterion A for Schizophrenia: requires that at least two of the items be present frequently, for much of at least 1 month. However, if delusions are bizarre or hallucinations involve "voices commenting" or "voices conversing," then the presence of this one item is required (American Psychiatric Association, 2013).

Criterion B: Dysfunction in one or more major areas of functioning (e.g., interpersonal relations, work or education, or self-care) (American Psychiatric Association, 2013). Note that educational progress is frequently disrupted, and the individual may be unable to finish school. Many individuals are unable to hold a job for sustained periods of time and the ones that are, normally are employed at a lower level than their parents. The majority of these individuals do not marry, and most have relatively limited social contacts (American Psychiatric Association, 2013).

Criterion C: Signs of the disturbances persisted for a continuous period (at least 6 months) American Psychiatric Association (2013).

There are several known subtypes of Schizophrenia (Paranoid, Disorganized, Catatonic, Undifferentiated or Residual), and its diagnose is based on the clinical picture of the individual (American Psychiatric Association, 2013).

The median age at onset for the first psychotic episode of Schizophrenia is in the early to mid-20s for men and in the late 20s for women (American Psychiatric Association, 2013).

3.3 Cerebral Palsy

CP is a common paediatric disorder that occurs in about 2 to 2.5 per 1000 live births worldwide (Jan, 2006). CP is strongly associated with gestational age and prematurity is the commonest risk factor, though the majority of affected children are full-term (Jan, 2006).

CP is a chronic motor disorder that results from a non-progressive insult to the developing brain that impairs motor function in children resulting in limitation to execute active daily life (Jan, 2006; Rahman et al., 2015). This wide variety of cerebral cortical or sub-cortical insults can happen during first year of life (Jan, 2006). However commonest cause of CP remains unknown in 50% of the cases (Jan, 2006).

CP means developmental delays and motor deficits (Jan, 2006; Rahman et al., 2015). Motor deficits of CP include negative phenomena such as weakness, fatigue, incoordination and positive phenomena such as spasticity, clonus, rigidity, and spasms (Jan, 2006; Rahman et al., 2015). CP can be classified according to the severity of motor deficits as mild, moderate, or severe (Jan, 2006). But, also can be classified according to the topographic distribution of motor deficits as monoplegia, diplegia, hemiplegia, triplegia, quadriplegia, and double hemiplegia. Note that the term paraplegia should not be used in this context as it implies a spinal cord injury involving the lower limbs only (Jan, 2006).

CP patients normally have multiple problems and potential disabilities such as mental retardation, epilepsy, feeding difficulties, and ophthalmologic and hearing impairments associated to their conduction (Jan, 2006). However not all CP patients are diagnosed with mental retardation, though there is a relationship between the severity of CP and mental retardation (Jan, 2006). Therefore, people diagnosed with spastic quadriplegic CP have greater degrees of mental impairment when compared with other subtypes of CP (Jan, 2006). In 36% of the cases children with CP have epilepsy, with onset in the first year of life in 70% of the cases (Jan, 2006). They can also manifest issues with growth that usually are linked to their feeding problems and mal nutrition, as well as, to orthopaedic abnormalities (Jan, 2006). Children with CP are, also, at increased risk for urinary incontinence as well as of constipation, due to the feeding problems mentioned above (Jan, 2006). CP patients can easily develop sleep disorders particularly those that already developed visual impairments (Jan, 2006). Drooling occurs in up to 30% of children with CP and is usually due to secondary mouth opening and/or swallowing difficulties due to pseudobulbar palsy. Hearing loss is also possible to happen due to certain aetiologies of the pathology (Jan, 2006). For these reasons patients with CP are best cared for with an individualized treatment plan, that requires the provision of a number of family-centred services (Jan, 2006).

3.4 Down Syndrome

DS or Trisomy 21 is the most common genetic cause of mental retardation and one of the few aneuploidies compatible with post-natal survival. This abnormality happens in 1 out of 700 live births worldwide (Sommer and Henrique-Silva, 2008).

Besides causing mental retardation, DS is associated with more than 80 clinical traits that includes congenital heart disease, duodenal stenosis, imperforate anus, Hirschprung disease, muscle hypotonia, immune system deficiencies, increased risk of childhood leukaemia, early onset Alzheimer's disease and so on. The severity of each of the phenotypic features can highly variable with the patient (Sommer and Henrique-Silva, 2008).

The genetic nature of DS encouraged, during the past few years the scientists to concentrate efforts towards the complete characterization of this chromosome, however the molecular mechanisms leading to DS are still incompletely understood (Sommer and Henrique-Silva, 2008).

4 Methodology

4.1 NAO Robot

4.1.1 NAO's Characteristics

NAO was the Robot adopted to the pilot study due to its simplified, hence accessible, human-like features. Further, note that according to the *state of art* presented in Chapter 2, NAO is not only one of the most used robot in scientific works, but also the most advanced and commercially available humanoid on the market. Moreover, the goal of this study 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 on 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.

As already mentioned, in the Chapter 2, NAO is considerate to be a humanoid robot, but even though NAO possess the human like characteristics that put it in

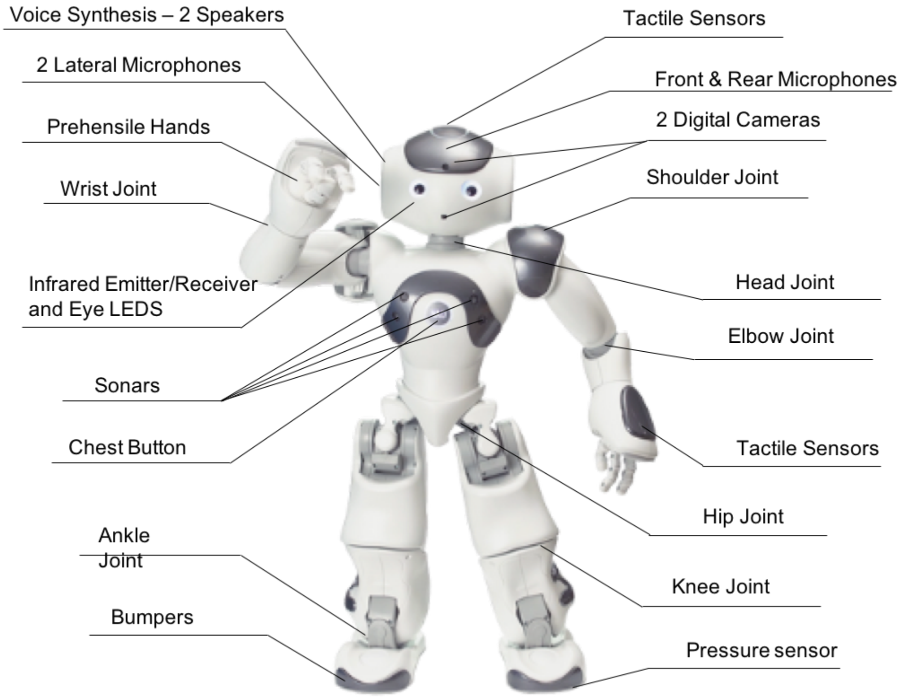

Figure 4.1 – NAO's humanoid robot system, (Softbank Robotics)

this category it has simpler features when compared to real humans (Shamsuddin et al., 2012a). NAO is a multi-functional, autonomous, programmable robot that can walk, speak, and even dance (Joglekar and Kulkarni, 2018; Othman and Mohsin, 2017).

It was developed by Aldebaran Robotics, a French robotics company, as a research platform in the field of HRI in 2006 (Joglekar and Kulkarni, 2018; Bertel and Hannibal, 2015). However, it was only in 2008 that this humanoid robot was introduced to the market (Shamsuddin et al., 2012b). By 2015 Aldebaran Robotics was acquired by SoftBank Group and rebranded it as SoftBank Robotics (Joglekar and Kulkarni, 2018).

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) (Bertel and Hannibal, 2015; SoftBank Robotics, a). NAO is pondered to be the most advanced and commercially available humanoid and it is, also, the most commonly used robot in HRI studies presented at international conferences (Shamsuddin et al., 2012a;

Bertel and Hannibal, 2015). It can provide friendly user programming through code or voice and facial recognition competences, in order to support HRI architecture during interventions (Shamsuddin et al., 2012a; Othman and Mohsin, 2017).

Due to all the points mentioned above, NAO is now highly used in computer and science classes from primary school through to university all over the Globe, as well as, in Industries, in education, research and healthcare (Bertel and Hannibal, 2015; Softbank Robotics).

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 (SoftBank Robotics, a; Ismail et al., 2012; Geminiani et al., 2019; Joglekar and Kulkarni, 2018). Therefore, NAO has nine tactile sensors, moreover, has two 2D cameras, four directional microphones, two sonars, bluetooth-ethernet-wifi connectivity, motors, a software running on built-in Naoqi Linux based operating system and it is powered by a LiPo Battery (SoftBank Robotics, b; Joglekar and Kulkarni, 2018; Ismail et al., 2012; Geminiani et al., 2019). The 2 VGA CMOS camera (640x480) and the four directional microphones are localized in the NAO's head and allow it, not only, to recognize shapes, objects and even people, but also, to interact with humans in up to 20 different languages (Softbank Robotics; Ismail et al., 2012).

NAO Robot is able to estimate its positional state through its inertial, bumper, foot contact, sonar and tactile sensors (Ismail et al., 2012) and it can either be programmed through *Choregraphe*, which is a very friendly user software that comes with the robot, or through Python or using a SSH (Softbank Robotics; Joglekar and Kulkarni, 2018).

4.1.2 Choregraphe

As mentioned in the previous section, NAO can either be programmed through *Choregraphe*, through Python or using a SSH (Softbank Robotics; Joglekar and Kulkarni, 2018). Therefore, in this study it was chosen to work with *Choregraphe*, which is a multi-platform desktop application that comes with NAO. Hence, *Choregraphe* is a very simple platform to work with, that can be easily manipulated with some informatics' ground knowledge.

So, *Choregraphe* is a multi-platform desktop application that allows, not only to create animations containing dialogs, services and powerful behavious, without the need of writing code, but also to test them on a simulated robot, or directly on NAO. Moreover, this platform also able the programmer to monitor and control the robot through it.

Choregraphe interface contains a **Menu Bar**, several different **Panels** and a **Toolbar** (Aldebaran Robotics, d). On figure 4.2 it is possible to see referred in orange the **Panels** of the *Choregraphe* main window, as well as the main buttons referred in green, which are part of *Choregraphe's* **Toolbar**.

The **Panels** are displayed, by default, as shown in figure 4.2 (Aldebaran Robotics, d). The Panel referred as A is where the project files are, on the other hand, panel B is the box library, where is possible to find all the *Choregraphe's* pre-coded animations (Aldebaran Robotics, d). Those animations are, by default, divided into thirteen categories:

Audio: Allows the user to either use applications of Sound, where the robot can play a specific sound or record it and so on, or use an application from Voice, which can allow the robot to speak, with or without speech recognition.

Behaviour: Manages a behaviour.

Communication: This application allows the user to use emailing, infrared signals or the network connection boxes, in order to either communicate or verify the connection state of the robot to the *Choregraphe* or to the Internet.

Data Edit: Allows to send or transform values.

Flow Control: Has options to control the flow, either, through timers and timelines or by parameters.

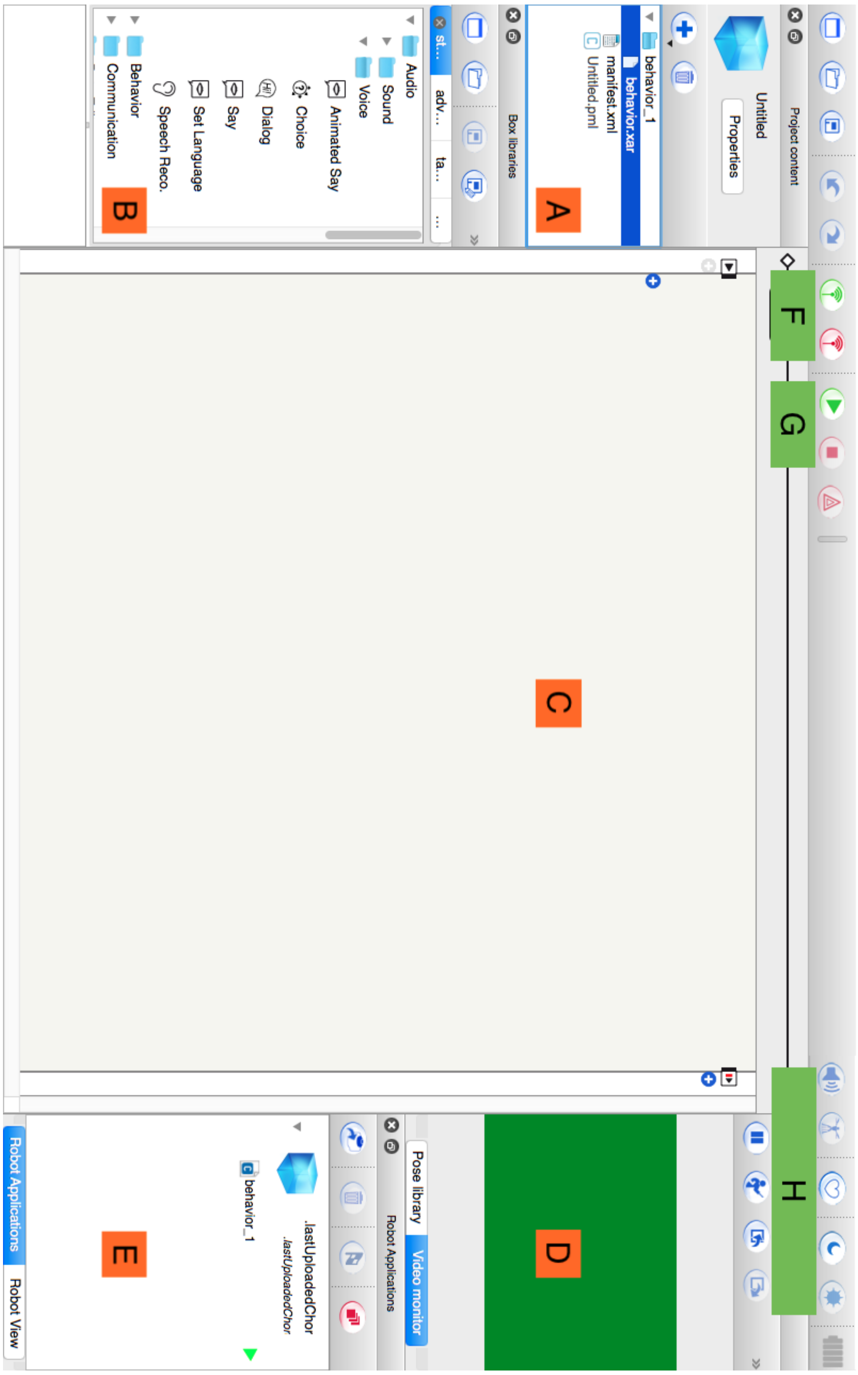

Figure 4.2 – Choregraphe main window, panels and buttons

LED's: Allows the user to control how the Robot's LED's blink and to which colour they can change to.

Math: This option allows to do math calculations with input values.

Motions: Controls all the motions that the Robot can perform.

Sensing: Controls the Robot sensors.

System: Controls the Robot system.

Templates: Provides several templates to use.

Trackers: Allows the Robot either to track sounds, movements, landmarks, a red ball, faces and people, as well as, to focus on a specific point or to point at it.

Vision: Allows to learn faces and do the respectively face detection and recognition.

World Representation: This box allows to push and remove objects that are stored at the WorldRepresentation.

Moreover, Panel C represents the Flow Diagram Panel, to where is possible to drag and drop the boxes from the previous Panel in order to create a new behaviour or edit a pre-existing one, with the purpose to create a flow diagram, which is a group of boxes linked with each other and with at least the input point (Aldebaran Robotics, b).

Further, the Panel referred as D, is where the Robot View and Video Monitor Panel are (Aldebaran Robotics, d). On one hand, the Robot View displays in a 3D view the robot that *Choregraphe* is connected to, as well as, allows the user to check and modify the joint values, in order to move the limbs, using the Limb properties (Aldebaran Robotics, e). On the other hand, the Video monitor panel displays in real-time what is seen by the camera of the Robot, allowing to teach NAO to recognize object and faces (Aldebaran Robotics, g).

Last but not least, the Panel E is the Inspector Panel and Robot applications Panel. The latest displays the available applications on the connected robot, which allows the user to manipulate behaviours and application installed, package and install the current behaviour as an application and to set a default behaviours (Aldebaran Robotics, f). While the other, displays properties of the selected behaviours or application (Aldebaran Robotics, c).

Regarding what concerns the **Toolbar**, buttons on the green F section are used to either connect, disconnect or try to reconnect your NAO to the *Choregraphe*. On the other hand, buttons on section G are use for play or stop the behaviours and application on the flow diagram. Moreover, the buttons on the H section allow the user to manipulate the state of the Robot, by activate or deactivate the Animation Mode, the Autonomous Life Mode, the Rest and Wake Up Modes. For more information about this topic please go to Aldebaran Robotics (a)

So, as described, NAO was designed to operate as autonomously as possible, and *Choregraphe* provides the programmer with tools, like dynamic dialogue boxes that can, also, do speech recognition in order to allow a fluent conversation with humans. However, speech recognition often fails in a noisy environment and there are other unexpected situations that can occur during dialogues, where the robot cannot correctly respond to requests, either because of the answer timing or if the human do not answer in between of what is expected to (Kanda and Ishiguro, 2013).

4.2 Experimental Design

The intervention involved two different approaches, a Game-Based Approach and a Robot-Based Approach, and the main goal is to assess if humanoid robot NAO can improve cognitive capabilities and joint attention time, of a mentally impaired group of young adults, when compared to a traditional game session with a new game with a humanoid.

4.2.1 Recognizing Colours - A Game-Based Approach

In the Game-Based Approach the operator used a *Power Point* presentation with a two level game visible in Appendix C, in order to catch the group's attention to the approach.

In the *Power Point* on slides of both levels it was present a one-colour drawing and a multiple choice, in order to the participants guess what colour was the drawing of. The difference between the two levels, is that in the first one the rectangles of the multiple choice were coloured with the corresponding colour that was written on it and an audio saying the colour name out loud whenever the operator hover the mouse over the option. On the other hand, in the second level, the rectangles of the multiple choice are all gray, but have the colour name written on them and the audio can also be played when the operator hover the mouse over the option, in case that the participant does not know how to read.

4.2.2 Recognizing Colours - A Robot-Based Approach

The Robot-Based Approach required a HRI, between NAO and the group members, in which the robot has to execute behaviours that are send by the operator *in loco* and in real time. Which means that the operator had to follow a 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

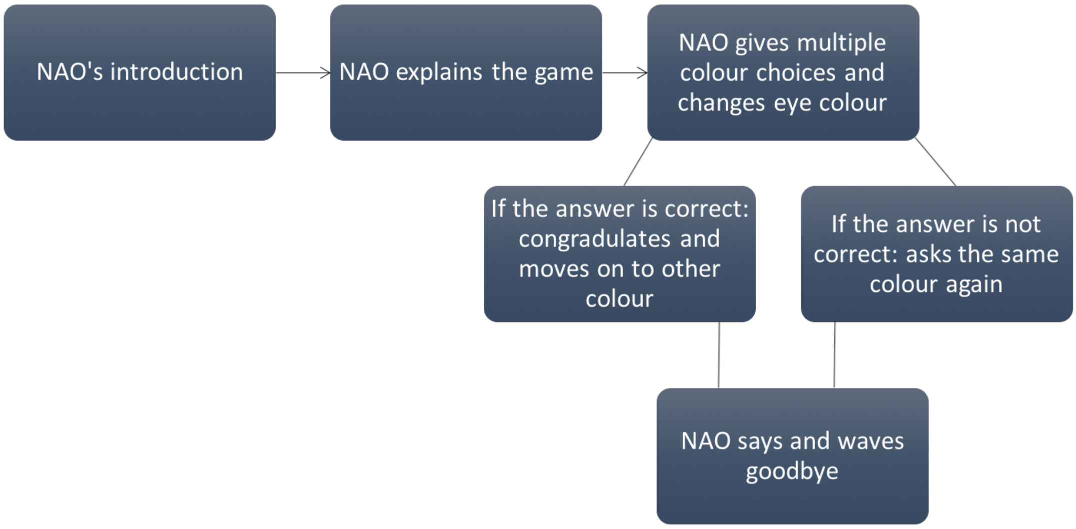

Figure 4.3 – Choregraphe flowchart

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 (Cao et al., 2018; Kanda and Ishiguro, 2013), which leads to the robot expecting another answer or for loops in the code.

So, 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 (Kanda and Ishiguro, 2013; Cao et al., 2018). 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 (Kanda and Ishiguro, 2013).

Therefore, a WoZ approach was safer to use, not only due to the reasons mentioned above, but also due to the reasons discussed, but also because this method is already well documented for persons with ASD and it has been proven to work properly in such cases.

In figure 4.3 it is possible to see a scheme of the behaviours used in the software, *Choregraphe*, that were programmed beforehand. Several *"Say"* and a *"Motion"* boxes were pre-programed, in order to be ready to be controlled by the operator at the sessions. Nevertheless, the objective of the script was to induce the participants to think that NAO was interacting with them autonomously.

So basically, the scrip tells NAO to start by introducing himself to the participants and by explaining the activity to the them. Afterwards, NAO is induced to asked the participants if they want to play a game and if they agree, NAO starts it. In this game, NAO's eyes colour change and the study group has to say what colour did the eyes 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 colour, and on the other hand, if they were incorrect NAO will show them the same colour again. This cycle repeats until all the colours selected, which in this case are four (yellow, blue, green and red), are covered.

In figure 4.4, it is possible to observe the *Choregraphe* script described above, divided by sections.

The red section is composed by a single *"Say"* box that allows the robot to do its introduction to the group. On the other hand, the dark blue section allows NAO to do the game explanation and to question the participants about their will to play the game.

Further, the green section is where the script of the colour based game is. There are several *"Say"* boxes, as well as, blink LED animations, that allow NAO to ask what colour its eyes will be at a determinate period, as well as, to allow its eyes' colour to change, respectively.

The *"Say"* boxes on the orange sections are meant to give the participants feedback about their answer. Moreover, the light blue box is only contemplated in the script for the eventuality of the study group does not want to play the game at a specific moment.

On the other hand, the yellow section is used for goodbyes and it it composed by a *"Say"* and a *"Motion"* box, that allow NAO to say goodbye to the study group, while it is doing a hand motion.

Hence, the main goal behind this approach was to realize if therapy sessions where

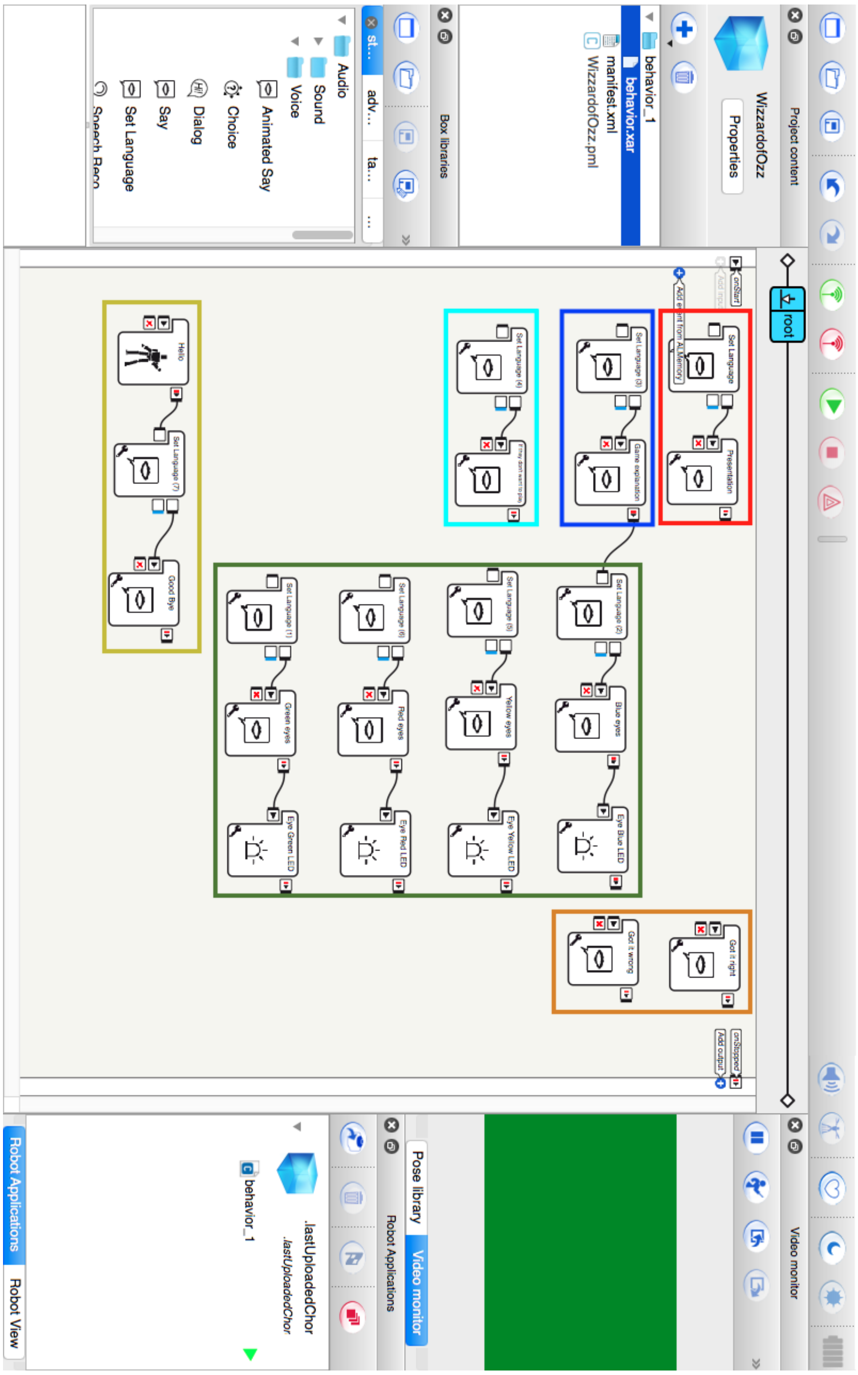

Figure 4.4 – Section of the Choregraphe script

NAO is used to improve cognitive skills of mentally impaired young adults can be used in individuals with other mental retardation beyond ASD. Therefore, the aim of this study was to test if this 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 is also important to understand if mentally impair young adults can focus better in the task when the activity is led by the humanoid.

Therefore, in order to achieve that the video and audio recording of each group session was essential, once that it allowed the operator to account the amount of times that each individual deviated their attention from the task, after the session happened.

5 Experiment

5.1 Participants

The chosen Institution to work with was an IPSS from the north of the country. An IPSS is an non-profit institution establish by private parties (Segurança Social, 2019). These Institutions normally aim to give expression to the moral duty of solidarity and justice among individuals that are not administrated by the Portuguese State or by any municipality, in order to either give support to children, young adults or families, to ensure the protection of the elderly or the disabled, in situations that there are lack of subsistence means or capacity to work, promote and protect health, give educational and professional training to citizens or to solve housing problems (Segurança Social, 2019).

In this specific case, this IPSS receives disable young adults with more than sixteen years, that after reaching the upper age limit for compulsory education are unable to proceed with regular education or to enter vocational training centers. Therefore, they create new opportunities for these citizens, in order to achieve social and professional integration

The IPSS has two Occupational Activities Centers and a Residential Home. After a meeting to present the study and the planned experiences, the technical directors of the Institution agreed that both Activities Centers had eligible candidates to participate in the study case. The study groups of this work involved twelve young adults and as it possible to see in table 5.1 8 out of the 12 participants were women and the other 4 were men. Hence, it is possible to observe that the know diagnoses of the study groups' members are really heterogeneous, though every one of them have learning and attention deficits in common.

Two sessions were carried, in each Center (*S1* and *S2*), with three groups each. Moreover, every group was submitted to two different approaches during their session time, a Game-Based Approach and a Robot-Based Approach.

It is important to mention 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.

S1, was during a morning period and had three different study groups (GA, GB and GC).

The first study group, GA, had three individuals (A1, A2 and A3) two women and one man, with an age ranging from 23 to 53 year old. Individual A1 has schizophrenia, A2 was diagnosed with a severe mental retardation, whereas A3 was diagnosed with cerebral palsy.

GB had an age ranging from 23 to 51 year old. The subjects were all women, B1 was diagnosed with a mental retardation and a motor disability, B2 with a cognitive retardation, while B3 has Down Syndrome.

On the other hand, GC was a group composed by men, with an age range from 45 to 59 years old. Individual C1 was diagnosed with a development delay and left spastic hemiparesis, subject C2 with a motor deficit, a cognitive retardation and with a language disorder, whereas C3 was diagnosed with a mild mental retardation and has sequels from a ischemic stroke.

The session *S2* took place in the second Activity Center and was performed during an afternoon period. Three different study groups participated in session *S2*, however reliable data could only be collected from the recorded videos of one of the groups.

Therefore, the only group of *S2*, GD, was composed by three women with an age range from 31 to 59 years old. D1 and D3 were diagnosed with cognitive retardation while D2 was diagnosed with cerebral palsy.

Table 5.1 – Group Members Medical Information

Individual	**Gender**	**Age**	**Diagnoses**
A1	Female	53	Schizophrenia.
A2	Female	60	Severe mental retardation.
A3	Male	23	Cerebral palsy.
B1	Female	51	Mental retardation and a 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.

It is considered that the variability of diagnoses, gender and age range of the group members it is not a disadvantage, once that it allowed to understand the interaction of each individual in each approach.

5.2 Ethics Statement

The study groups used in this research involved young adults with mental impairments. This research was submitted to the Ethics Committee of UTAD, their consent to conduct the study can be consulted in Appendix A.

An express Informed Consent similar to the one presented in Appendix B, was sign by the IPSS allowing the young adults to participate in the research. The Informed Consent assures that the personal data of the participants is enclosed and all the private information collected during the session is confidential and anonymity was guaranteed at all times.

5.3 Pilot Studies

The proposed pilot study described in section 4.2 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. The study group was described in the previous section. An illustration of the experimental setup used on both approaches can be observe on figure 5.1, while an actual picture of the setup is shown in figure 5.2. The experimental setup 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 camera was used to record each group during both approaches, in order to afterwards allow the operator to collected data about the state of attention of the participants.

The guardian and the operator were placed on both sides of the robot and of the computer, respectively. Note that NAO's head and the computer screen were placed at participants' eye height, in order to be more easy 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

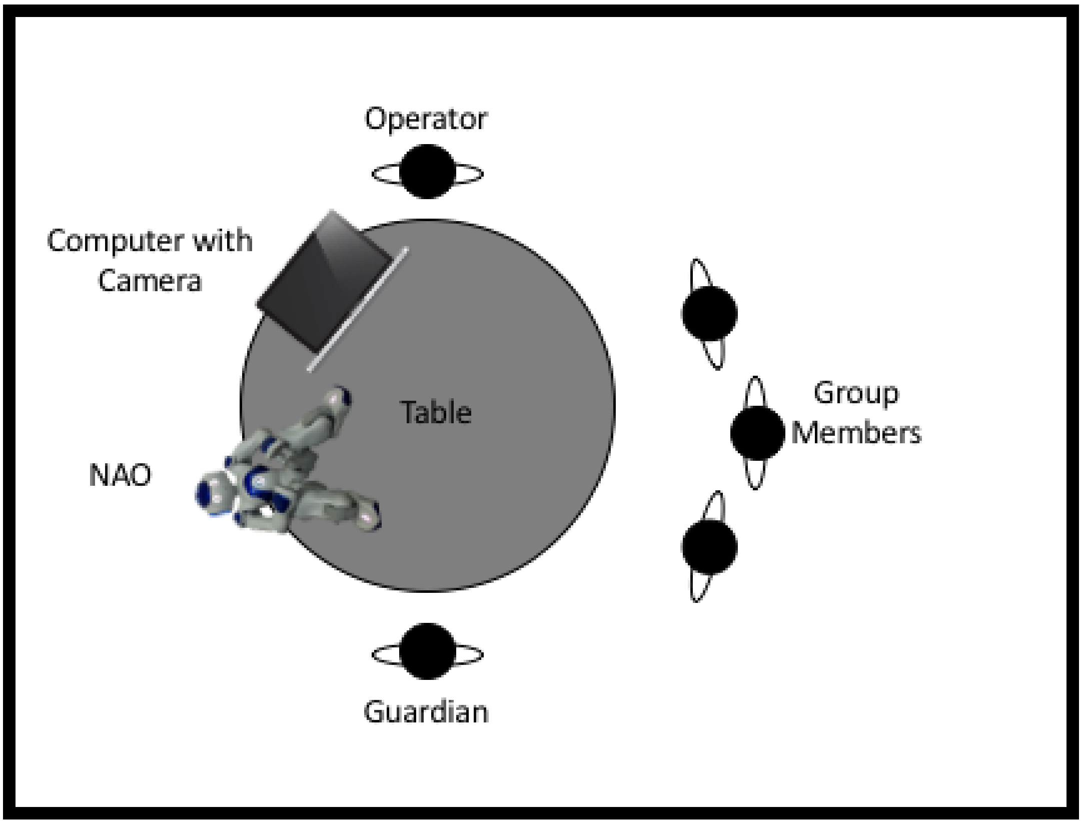

Figure 5.1 – Illustration of the experimental setup

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.

So, 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 first 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 5.4 it is possible to see the flowchart that describes the events.

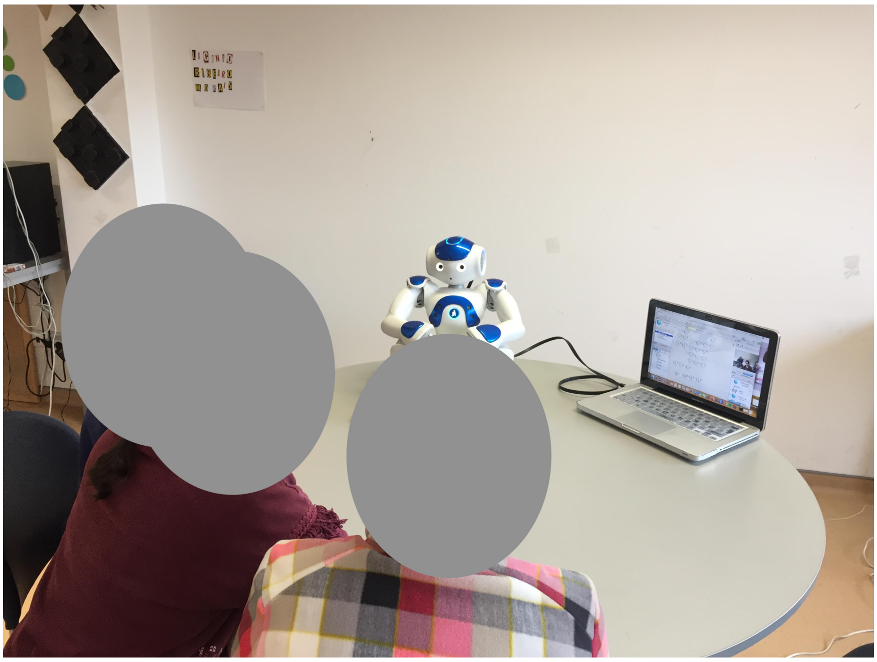

Figure 5.2 – Actual experimental setup

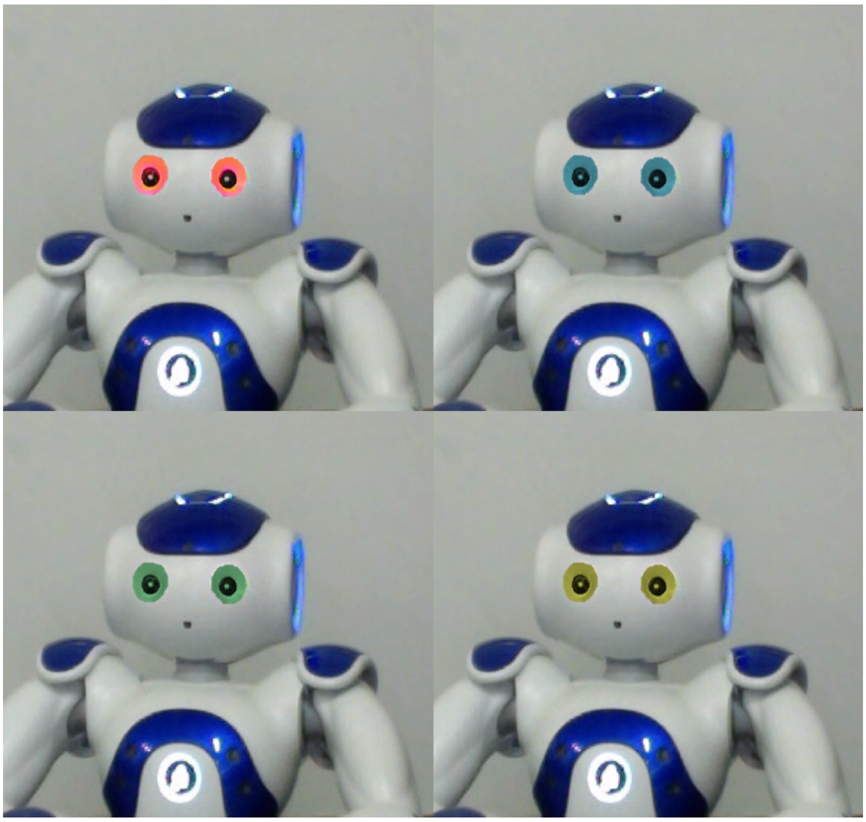

Figure 5.3 – Illustration of NAO's eye colour change

Furthermore, after each session the operator would give the command so that NAO would perform a *Tai Shi* presentation as a bonus reward to the well-behaved participants. This was performed with all participants and they were not aware of the reward until the operator final goodbye.

In the majority of the groups both approaches had the same time range for observation, however in one of the groups, GB, the operator took twice the time observing the participants behaviour during the Robot-Based Approach, in order to understand if their behaviour would be the same after the doubling their time doing the same activity with NAO.

Note that the Game-Based Approach was designed to be as appealing and engaging as possible, having two levels instead of one in order to be less monotonous than the activity with NAO, that had just one level. This approach was intended to work as a control session that could enable the comparison between the participants joint attention in both approaches. This simple game helped to compare the participants behaviour and to eliminate novelty as a factor. On the other hand, in the Robot-Based Approach NAO was the main vehicle used to catch the group's attention.

Further, all the group's sessions were video recorded, in order to take in account the amount of times that the participants looked away or were distracted during the activities. This allowed to understand in each activity were the participants more focused on.

5.3.1 Robot-Based Approach

After the first introduction of the operator, all groups are compelled to engage in the Robot-Based Approach. The operator would give NAO the command to introduce itself, as well as, to explain the game, followed by the start of the game where NAO would change its eye's colour and the group would have to give him an answer. After the group's answer, the operator loads another command telling NAO whether to complement the group for the correct answer, or to ask them to guess again in case of

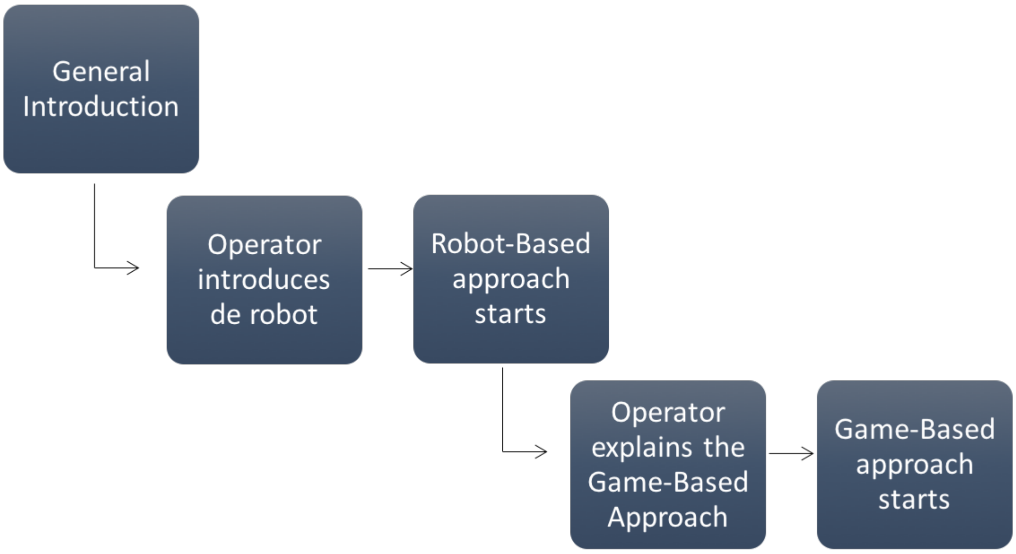

Figure 5.4 – Flowchart of the activities performed

incorrect answer. Than, the operator would load a command with a new eye LED colour or the same, respectively, and the cycle would repeat until all the colours (yellow, blue, green and red) were guessed correctly. Figure 5.3 is possible to see a scheme of how NAO's eye LED's change colours. In the end of the flow diagram, the operator would send NAO a command to "wave goodbye" and to verbally express the end of the game.

5.3.2 Game-Based Approach

The operator would start the Game-Base Approach by explaining thoroughly the activity to the groups. After they understand the main goal, it was possible to do an example demonstration that would, also, help them understand how the game was played. Afterwards, the operator would conduct the game by changing slides and asking the participants, either as a group or as an individual, the answer to a certain question. Once again, the computer's manipulation was all made by the operator, due to n possible limitation of the group's members and as a security measure. In the end of the *Power Point* presentation, the operator would say to the study group that the activity ended and say her goodbyes.

6 Results

During both approaches the variable evaluated was the joint attention and the eye gaze of the participants during the respective session. As mentioned before, the Game-Based Approach was brought to the groups sessions in order to serve as a control. Therefore, further comparisons made in this chapter will be between the data collected in the two approaches described in the previous one.

It is important to always take in account, not only, how long each session lasted, but also, how many times were the interveners distracted during that time. So, it is important to recall that every group had sessions of five minutes in both activities, with the exception of GB, that had a ten minutes Robot-Based Approach.

In order to get to the amount of times that each individual deviated their look during both approaches, the sessions were recorder to allow the operator to number the times when it happened. It is important to understand that in some cases the participants were distracted just because they would feel like it, and no distracting agents would take part in it, so in these cases the participant is considered to be "Self-distracted". When a distracting agents, such as, noises or persons coming in and out of the room, happened and was motive of distraction, the participant was induced to look away and it would count to the "Total" amount of times that this individual looked away. Further, in the Robot-Based Approach once that the operator briefing was not part of the approach, the amount of times that the participants were considered to be distracted was not accounted for, and for that reason they will not be shown in the "Total". Moreover, in this approach, when it is claimed that there was "No Interaction" happening it is because NAO was waiting for a command to load and the activity was frozen.

Furthermore, once that one of the variables is the joint attention, every time that the operator would intervene and the participants would look at her for guidance would not be accounted has distraction.

6.1 Results Presentation

In tables 6.1, 6.2, 6.3 and 6.4 it is possible to see the participant denomination, the information about what happened in each session and a section for additional comments.

In **GA**, the duration of both approaches was approximately five minutes and the results observed during sessions can be consulted in table 6.1.

Table 6.1 – Results of GA from both approaches

Individual	Game-Based Approach	Robot-Based Approach	Comments
A1	Looked away once during the operator explanation time and one other time when asked to wear a coat. Therefore, A1 was distracted **twice in total**, being **self-distracted once**.	This individual **was never distracted** during the robot intervention, once that A1 only looked away twice when the operator was introducing herself and NAO.	None.

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Table 6.1 – *Continued from previous page*

Individual	Game-Based Approach	Robot-Based Approach	Comments
A2	This participant was distracted four times before a noise happened, the noise was itself a distraction. Afterwards, A2 looks away twice and was also distracted by a person that entered the room. A2 was found distracted thirteen more times, however in one of these times there was no interaction. Therefore, A2 was found to be distracted **twenty times in total**, being **self-distracted seventeen times**.	Looked away ten times when the operator did the briefing, and was distracted twelve times during the robot intervention, however **in seven of this times there was no interaction happening**. Therefore, subject A2 was distracted **twelve times in total**.	None.

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Table 6.1 – *Continued from previous page*

Individual	Game-Based Approach	Robot-Based Approach	Comments
A3	Was distracted once before a noise happened. Similarly, to what happened with subject A2, A3 was also distracted by the noise. Afterwards, A3 looked away one more time. Therefore, A3 was found to be distracted **three times in total**, being **twice self-distracted**.	A3 divided the attention between the operator's briefing and NAO, looking away twice. After it, A3 was distracted **four times, in total**, and in each one of them **there was no interaction happening**.	None.

In **GB**, the duration of the Game-Based Approach (five minutes) was half of the Robot-Game Approach (ten minutes). The results observed during both approaches can be consulted in table 6.2

Table 6.2 – Results of GB from both approaches

Individual	**Game-Based Approach**	**Robot-Based Approach**	**Comments**
B1	Paid attention during the briefing about the game, and during the actual game kept focus in the activity even when the other group members were individual questioned, **not being distracted even once**.	B1, also, did not look away once during this intervention.	None.

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Table 6.2 – *Continued from previous page*

Individual	**Game-Based Approach**	**Robot-Based Approach**	**Comments**
B2	The individual paid attention during the operator's explanation time, like individual B1, however B2 looked away **three times in total** during the game.	B2 looked away **once in total**.	It is important to say that B2 tried to **encourage and help the other group members** in their individual time. Morover, B2 **asked for additional instructions** when needed. Also, B2 tried to **interact with the robot**, asking it for a hand shake and to move and speak and send NAO kisses

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Table 6.2 – *Continued from previous page*

Individual	Game-Based Approach	Robot-Based Approach	Comments
B3	B3, on the other hand, looked away three times during the game briefing and thirty-four times during the game. Therefore, B3 was found to be distracted **thirty-seven times in total**.	B3 looked away eleven times during my self-presentation and briefing. Afterwards, B3 was distracted eleven times before a noise happen and the noise itself was also a distraction. Afterwards, B3 looked away ten more times. Therefore, subject B3 was distracted **twenty-two times in total**, being **self-distracted twenty-one times**. However **in eight of those times, there was no interaction happening**.	It is important to note that **the periods that B3 look away during NAO's intervention were overall smaller than in the Game-Base Approach**, keeping the **focus in the robot** every time that it spoke.

In **GC**, the duration of both approaches was approximately five minutes and the results observed during sessions can be consulted in table 6.3.

Table 6.3 – Results of GC from both approaches

Individual	Game-Based Approach	Robot-Based Approach	Comments
C1	Looked away **eleven times** during the game, however in some of those it was to glimpse the partner that was answering.	Looked away three times during the operator explanation and **three times** during the intervention, however **in two of those times there was no interaction happening**. Therefore, C1 was found to be distracted three times in total.	None.
C2	Was distracted **four times in total**.	Was found distracted **three times and there was no interaction happening** in none of those times.	C2 would **answer discreetly even when it was the individual time of other group members**.

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Table 6.3 – *Continued from previous page*

Individual	Game-Based Approach	Robot-Based Approach	Comments
C3	Looked away **three times in total**, however **in two of those**, C3 was **looking to the group member that was being questioned**.	Deviated the attention **three times**, however **in two of those** times **C3 was making comments about the robot** with C2 and **in one of those** three times there **was no interaction happening**.	C3 was found to be more **focused on NAO during my briefing** than in me. It is also important to note that C3 **tried to help the other group members**.

In **GD**, the duration of both approaches was approximately five minutes and the results observed during sessions can be consulted in table 6.4.

Table 6.4 – Results of GD from both approaches

Individual	Game-Based Approach	Robot-Based Approach	Comments
D1	D1 **focused on NAO twice** during this approach, after that, a noise and a person were motive of distraction four times in a row, than D1 asked to go to the restroom, but before that looked away one more time. Afterwards, D1 looked away four times, before a person became a distraction itself. D1 was found distracted two more times before the person became again a distraction. D1 looked away three more times before the end of the game. Therefore D1 was found to be distracted **eighteen times in total**, being **self-distracted twelve times**.	D1 looked away several times during the operator briefing, after that, D1 was found to be distracted twice before a noise happen, and the noise itself became a distraction. D1 looked away one more time before a person enter the room and becomes a distraction too. D1 was self-distracted three more times until a person was again a distraction. It is important to mention that **NAO was performing in just one of those distractions times**. Therefore D1 was distracted **nine times in total** and was **self-distracted six times**.	D1 was in the **restroom for two and half minutes**.

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Table 6.4 – *Continued from previous page*

Individual	Game-Based Approach	Robot-Based Approach	Comments
D2	Was distracted by a person, five times, during the game and looked away fourteen more times. Therefore, D2 was found to be distracted **nineteen times in total**, being **self-distracted fourteen times**.	Looked away twice during the operator's introduction time. Afterwards, D2 was found to be distracted twelve times before a person came in to the room and became a distraction twice. D2 looked away five more times, before the end of the intervention. However, **in only five of those times the robot was being interactive**. Therefore, D2 was found to be distracted **nineteen times in total**, being **self-distracted seventeen times**.	None.

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Table 6.4 – *Continued from previous page*

Individual	Game-Based Approach	Robot-Based Approach	Comments
D3	Was found to be distracted throughout the game by a person or a noise six times and looked six more times away. Therefore, D3 was found to be distracted **twelve times in total**, being **self-distracted six times**.	Looked away nine times before a person came in to the room and became a distraction twice, D3 was found to be distracted once in the period between the two times that the person was a distraction. It is important to mention that **D3 was distracted during NAO's intervention only three of those times**. Therefore, D3 was found to be distracted **twelve times, in total**, being **self-distracted ten times**.	None.

6.2 Discussion of Results

In order to better understand the previous results several graphs were made. In those graphs, it is possible to see the results of each group individually. For each group member, the results of the Game-Based Approach (G) and of the Robot-Based Approach (R) are always presented in three different categories: "Total",

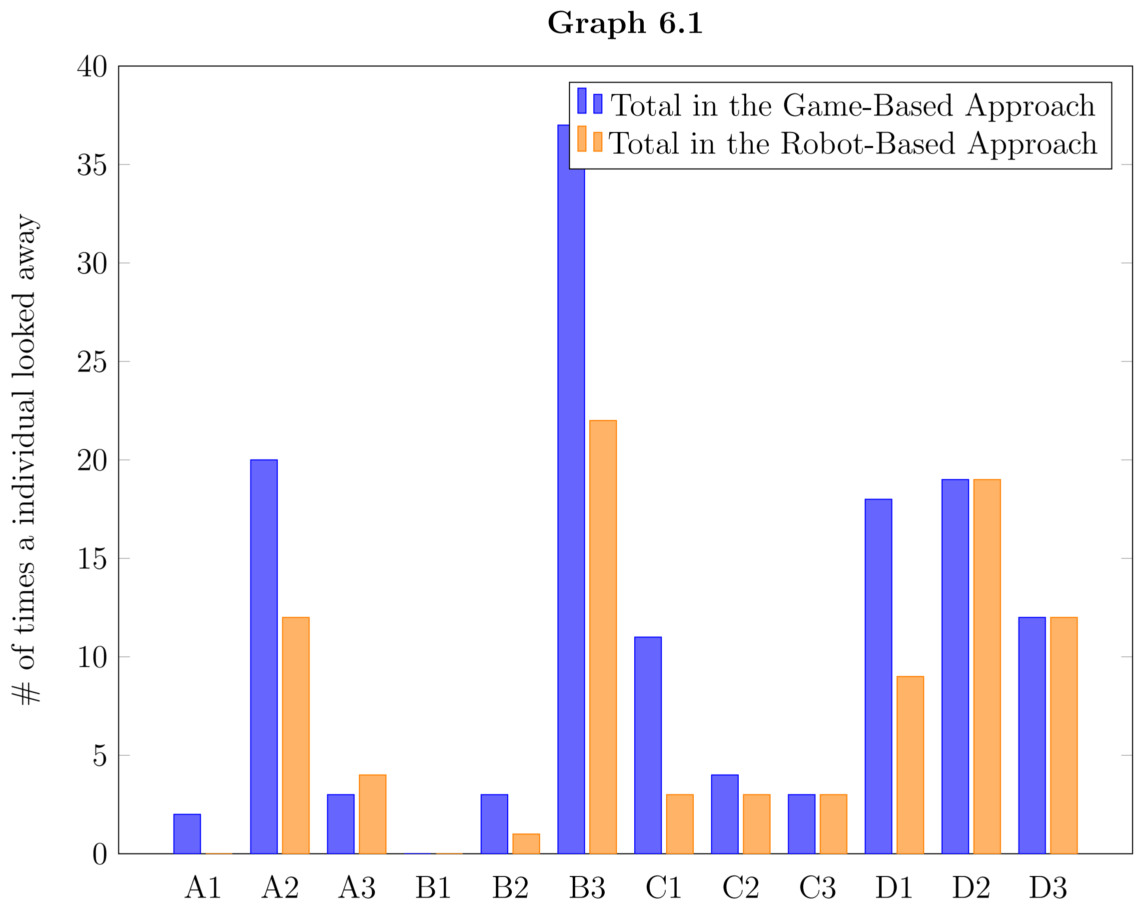

Figure 6.1 – Number of time that an individual looked away in both approaches

"Self-distracted" and "No Interaction". The "Total" stands for the total amount of times that an individual looked away during the intervention, with or without external distractions. On the other hand, the "Self-distracted" includes only the number of times where the individuals were not disturbed by any distracting agent. Moreover, the "No Interaction" category takes only in consideration the amount of times that the participants looked away when there was no interaction happening with NAO, in the Robot-Based Approach.

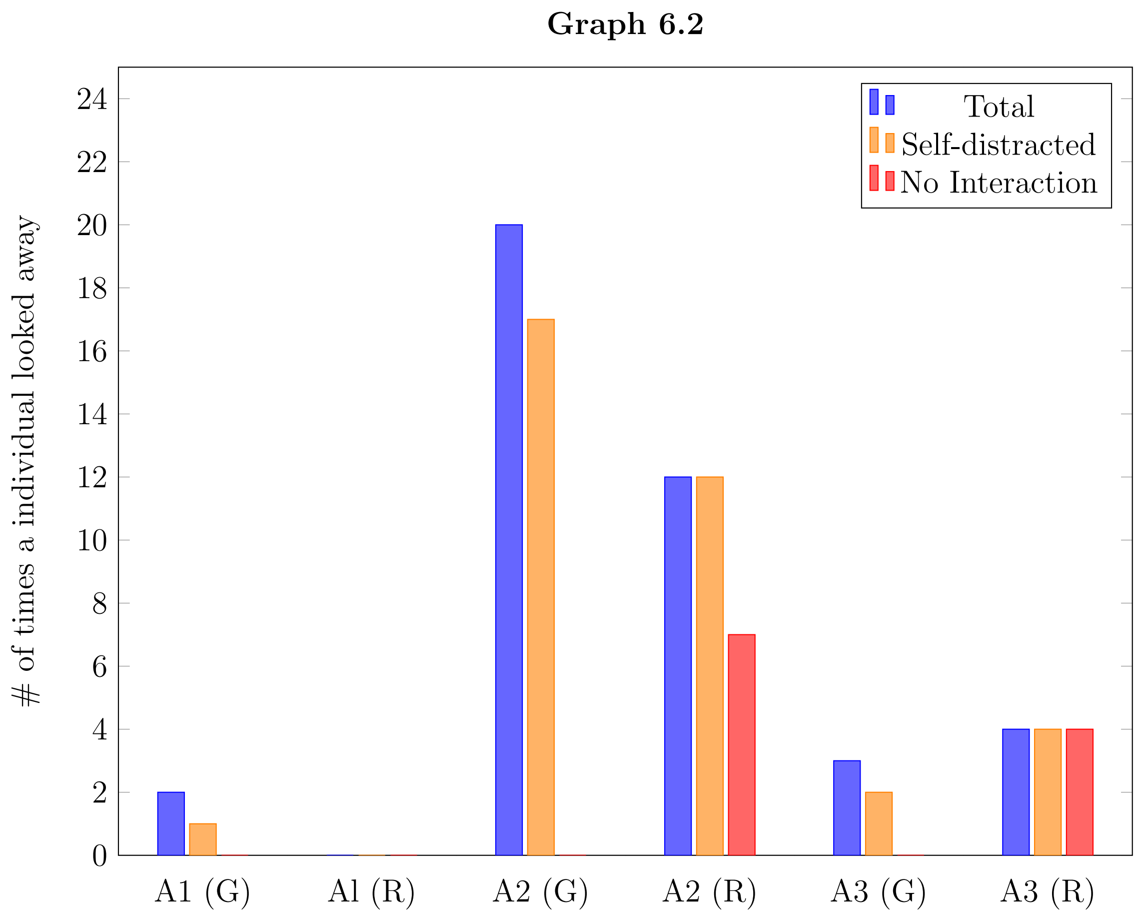

Figure 6.2 – Results of GA from both approaches

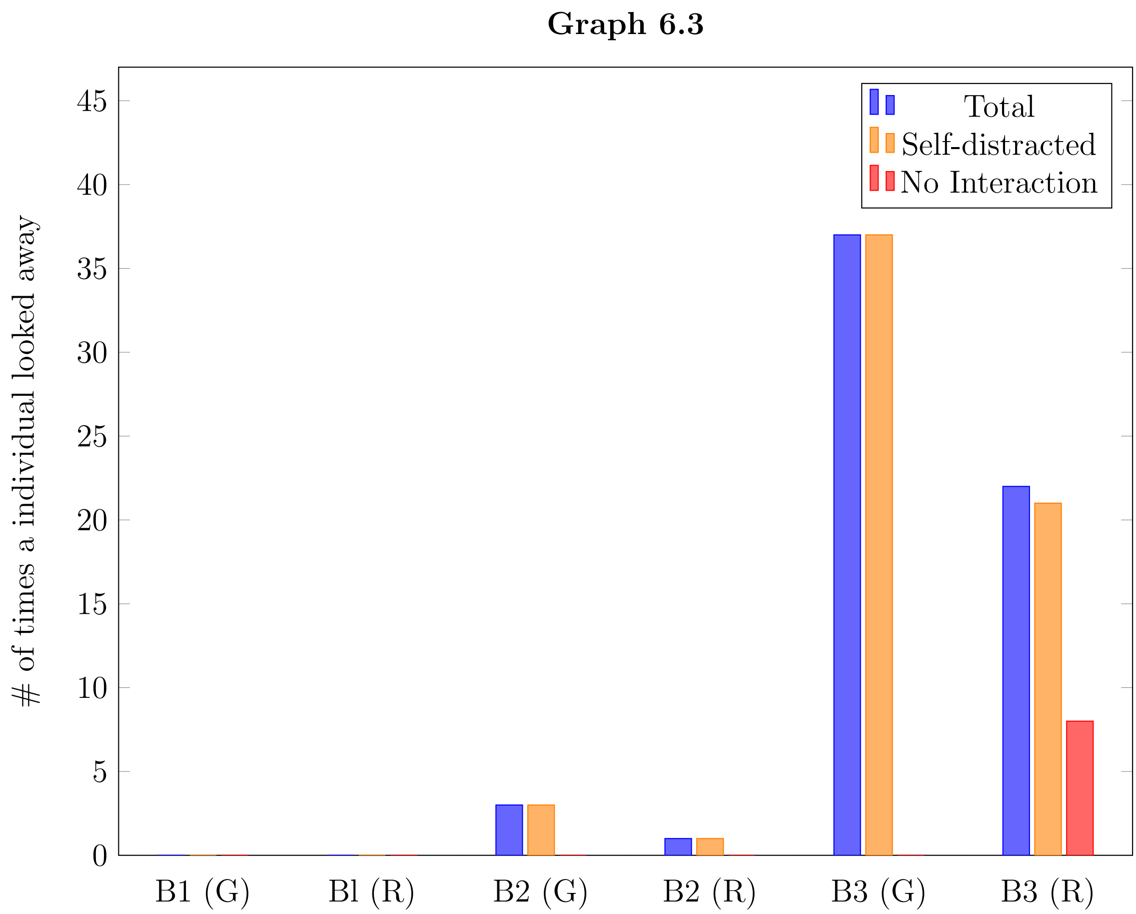

Figure 6.3 – Results of GB from both approaches

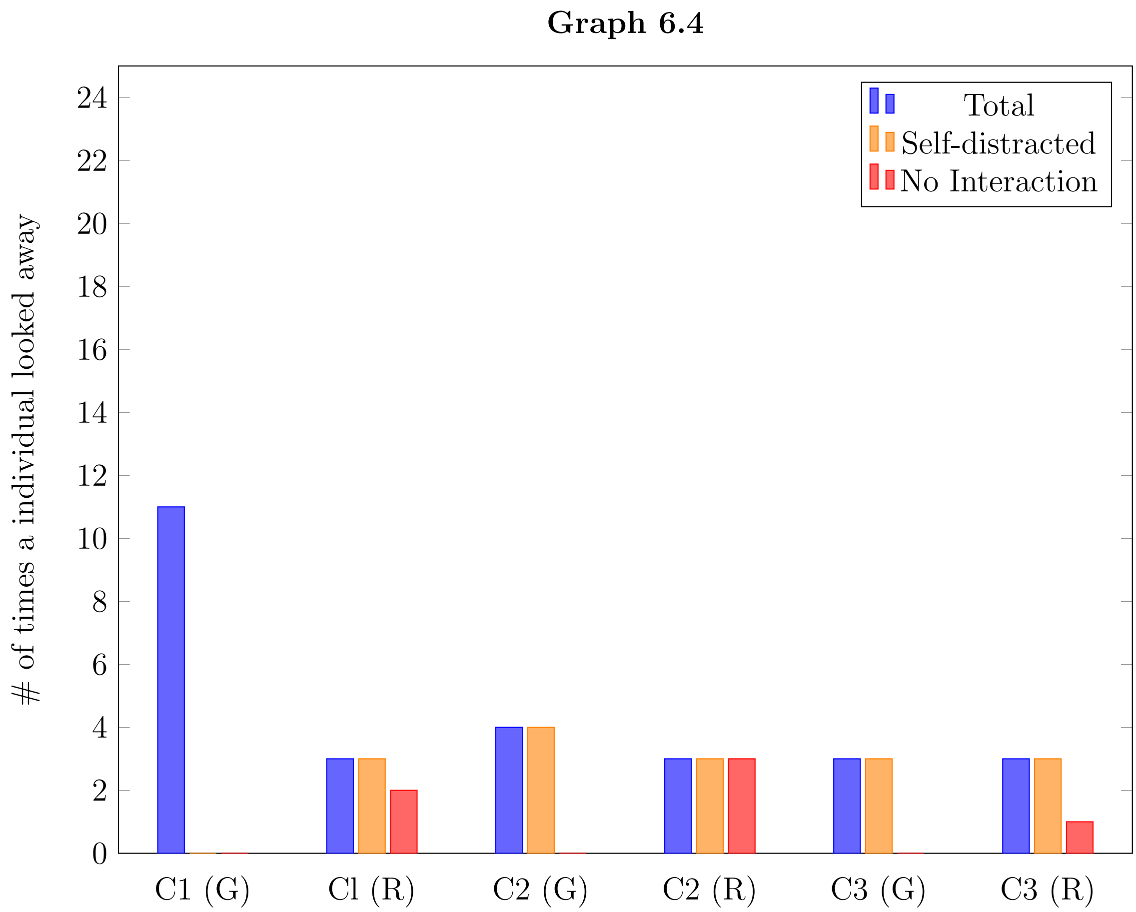

Figure 6.4 – Results of GC from both approaches

By looking at figures 6.1, 6.2, 6.3, 6.4 and 6.5, at first glimpse it is possible to see that when comparing the times, in total, that an individual looked away in both approaches, seven out of twelve participants (A1, A2, B2, B3, C1, C2 and D1) were more distracted during the Game-Based Approach than during the Robot-Based Approach. Moreover, just one of the participants (A3 from figure 6.2) was more

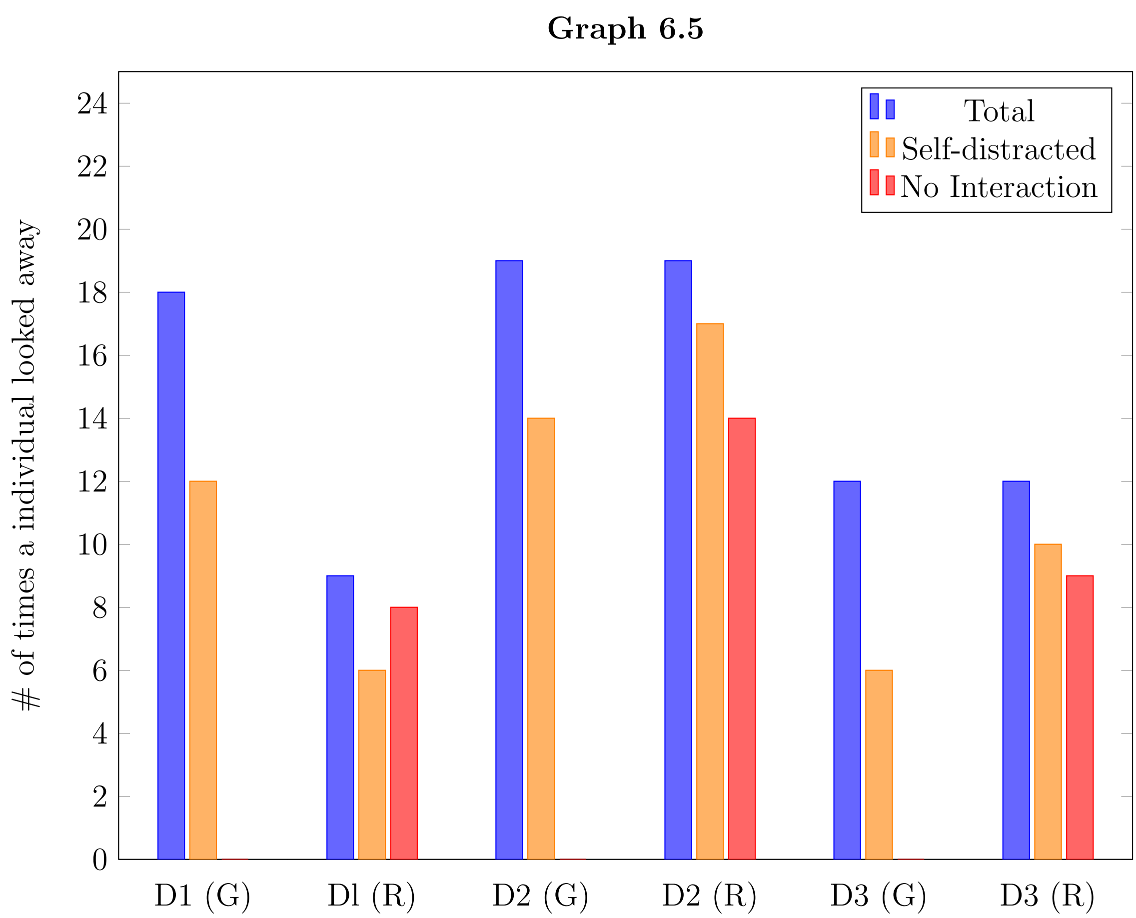

Figure 6.5 – Results of GD from both approaches

distracted during the Robot-Based Approach. The remaining four participants (B1, C3, D2 and D3) looked away the same amount of time during both approaches.

However, if 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 ten out of twelve of the participants were more focused on the Robot-Based Approach. Hence participant C1 was more distracted in that approach, which means that the individual was more focused in the Game-Based Approach. Moreover, participant B1 did not look away on either approaches, however B1 was part of the group where the Robot-Based Approach was longer than the Game-Based Approach, being focused in the activity for twice the time.

It was also interesting to understand that even in the group described above, GB, the participants either were more focused in the Robot-Based Approach, looking away less than half of the times during the intervention (B2 and B3), or kept their focus in both activities (B1). Moreover, in the case of participant B3 it was also possible to verify that this individual kept looking away for longer periods in the Game-Based Approach than in the Robot-Based Approach. Furthermore, I also observed that when NAO talked, B3 would always focused on it.

Hence, several were the participants that treated NAO as a social being, either by trying to talk to it or physically interacting with it.

Thus, it can be stated that NAO can be a useful tool in mental impairments other than ASD, once that it was establish that NAO can influence eye gaze and joint attention during the sessions. Nevertheless and even though NAO helped the study group with their joint attention, it would not be an effective tutor by itself.

7 Conclusions and Future Work

7.1 Conclusions

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. However, there is still a long way when it comes to mentally retarded individuals, once that little has been accomplished over the past few years. Which is considered to be a major lacuna between the Robotic scientific research field and to a potential clinical application.

However, and even though mentally retarded individuals are considered to be a group of interest to potential clinical application of Robot-assisted therapy, as mentioned above, 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, throughout the analysis of Section 6.2 of Chapter 6 it is possible to conclude that the results from both sessions with the study groups were actually positive once that it was proven that young adults with mental impairments, other than ASD, can improve their focus during a task with NAO rather than with a computer task. Not only, the creation of a stimulating learning scenario with NAO (Goal 1, Section 1.2.1) was achieved, once that the group's members felt excited to freely answer to the NAO's questions, even though they were answering with knowledge that was previously acquired. But also, it was possible to access the efficiency of NAO as a teaching tool that is able to capture the group members' attention (Goal 2, Subsection 1.2.1), once that during the Robot-Based Approach was notorious an increase in the joint attention of the participants.

Regarding to Question 1 and 2 from Subsection 1.2.1, it was verified that the interaction of the study group does in fact changes when in presence of the humanoid NAO, paying in overall more attention during NAO's approach than during the computer game one. Thus, it was considered that NAO does improved eye gaze and joint attention of the participants. Hence, Hypothesis 1 and 2 exposed in Subsection 1.2.1 where proven to be true.

Therefore, once that NAO has shown that it was capable of improve the group members' eye gaze, increase their joint attention during session, as well as, capable of interacting with them without any tantrums or resistance behaviour, makes sense that NAO could start to be applied as a useful tool in several types of sessions with mental impaired young adults' other than just with Autistic individuals. Moreover, NAO prove to be an important sensorial stimulus to those individuals in several areas, once that it was found that the participants would be more comfortable answering to the robot rather to the human operator. This, allows to conclude that HRI can play a crucial role in the lifes of mentally impaired individuals

Although this study has presented itself as an overall success, there were some throwback during sessions, that could be hence in future approaches.

So, and 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 colours, during the Robot-Based Approach. Which could also be due to the internet connection issues.

NAO is a considerably efficient tool that should be applied in IPSS like this one, 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.

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.

7.2 Future Work

Future work, should not only focus on addressing the shortcomings described in the Section above, but also in some other crucial question.

One of the first changes that should be considered, in future approaches, is the changing of programming platform, in order 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, individual questions were asked to better understand the participants' dynamic in both approaches, therefore, I think that in future approaches it would be more advantageous to only have an individual at a time instead of groups.

Furthermore, in future approaches, 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 kept focused on NAO in future approaches it should be done a continuous study during several months, with session once to twice a week.

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A Appendix

UTAD's Ethical Committees Opinion

UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO utad

COMISSÃO DE ÉTICA

PARECER

Título: Aplicação do Robot NAO ao desenvolvimento de capacidades cognitivas.
Ref: Doc86-CE-UTAD-2019

Cara Aluna Ana Freire,

A Comissão de Ética da Universidade de Trás-os-Montes e Alto Douro (CE-UTAD) analisou a sua submissão para obter uma avaliação ética para o projeto mencionado acima.

Os seguintes membros da CE-UTAD participaram na avaliação ética:

Nome	Qualificação	Papel na Comissão de Ética	Gênero	Afiliação à UTAD
Eurico Vasco F. Amorim	Professor	Membro/Presidente	M	Sim
Isabel O´Neill M. Gaivão	Professor	Membro	F	Sim
José Albino G. Alves Dias	Professor	Membro	M	Sim
Maria Cristina Q. Antunes	Professor	Membro	F	Sim

A CE-UTAD está a trabalhar baseada na Declaração de Helsínquia (Princípios ICH-GCP), em conformidade com as Diretrizes da Schedule Y / ICMR, na Convenção de Oviedo e outros regulamentos aplicáveis. Nenhum dos investigadores deste estudo participou na tomada de decisão e no voto desta avaliação.

Com base na revisão da documentação do projeto, a CE-UTAD declara um Parecer Ético Favorável por unanimidade sobre a solicitação apresentada.

Alerta para a conveniência de não identificar a entidade, mas apenas apresentar como um estudo numa IPSS.

A CE-UTAD espera ser informada sobre o andamento do estudo, sobre quaisquer eventos adversos graves ocorridos no decorrer do estudo, ou qualquer revisão do protocolo e solicita uma cópia eletrónica do relatório final.

UTAD, 13 de janeiro de 2020

Eurico Vasco Ferreira Amorim
Presidente da Comissão de Ética da UTAD

E-mail: comissaoetica@utad.pt

QUINTA DE PRADOS | TEL. 259 350 000
5000-801 VILA REAL | FAX 259 350 480
Portugal

B

Appendix

Model of the Informed Consent given to the IPSS

INFORMED CONSENT FOR PARTICIPATION IN RESEARCH

according to the Helsinki[1] Declaration and the Oviedo Convention[2]

Please read the following information carefully. If you think something is incorrect or unclear, don't hesitate to ask for more information. If you agree with the proposal made to you, please sign this document.

Study Title: Application of NAO Robot to the development of cognitive skills.

Framework: Within the scope of the Master in Biomedical Engineering of Ana Maria da Cruz Freire from the School of Science and Technology of University of Trás-os-Montes and Alto Douro, supervised by Professors António Luís Gomes Valente and Vítor Manuel de Jesus Fillipe, the student intends, with the agreement of the IPSS, to observe if the interaction between a humanoid and young adult with mental disabilities brings benefits to their joint attention and stimuli of their cognitive abilities.

Pilot Study: The study involves the collection of behavioural data from young adults with mental disabilities, through video and audio recordings, during two approaches, the Game-Based Approach and the Robot-Based Approach. The video and audio recordings made during the sessions will be destroyed as well that the dissertation is defended.

The Game-Based Approach it is intended to be the control session, eliminating the novelty factor of the trial. In this approach, a computer game will be introduced, where users will have to indicate the colour of the form that is presented to them in a slide. Likewise, in the Robot-Based Approach, a game also will be introduced, but this time by the humanoid NAO, in which the participants will have to indicate what colour the robot's eyes are at different times. In both approaches, the level of joint attention will be assessed.

The study groups were selected by the technical directors and teachers of the Institution. For participants' convenience, two sessions will occur, one in the during the morning period and one in the evening period in the Institution's facilities.

Conditions and funding: Since both sessions will be held at the Institution's facilities, the study will not involve any kind of travel or costs for the participants. Participation in the study is voluntary, and there are no welfare or other losses if you do not accept to participate.

Confidentiality and anonymity: All data collected during both sessions will be used exclusively for the present study. All the identification data of the participants will not be recorded and/or made public. Total anonymity to the participants is ensured.

Best regards,

Ana Maria da Cruz Freire, student of the Master in Biomedical Engineering of UTAD, 913883124, ana.freire.04@hotmail.com,

Signature: … … … … … … … … … ... … … … …... … … … … … … … … … … … …

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I declare that I have read and understood this document, as well as the verbal information provided to me by the person/s who signed above. I was guaranteed that the possibility to refuse to participate in this study could happen at any time without any consequences. Therefore, I accept to participate in this study and allow the use of the data that I voluntarily provide, trusting that they will only be used for this investigation and in the guarantees of confidentiality and anonymity that are given to me by the investigator.

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Signature: … … … … … … … … …... … … … … … … … … … … … … … … … … … … … Date: …… /…… /………..

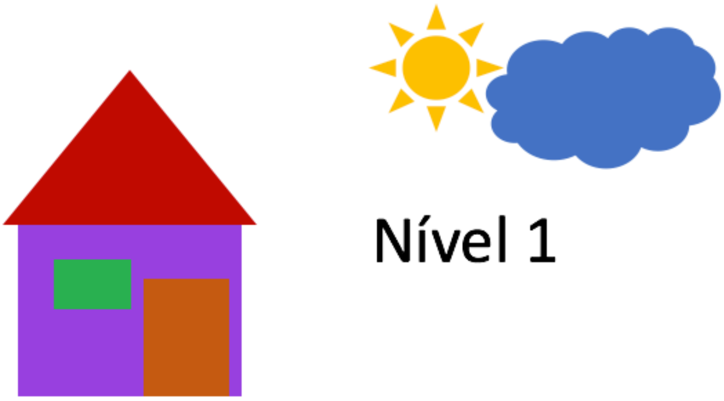
IF IT IS NOT THE PERSON TO SIGN BY AGE OR DISABILITY (if the minor has discernment he must also sign on the top, if he/she consents) NAME: … BI/CD Nº: .... EXPIRE DATE ….. /….. /…….. DEGREE OF RELATEDNESS OR KIND OF REPRESENTATION: .... SIGNATURE: …

THIS DOCUMENT IS COMPOSED BY 2 PAGES AND A DUPLICATE WAS MADE:

ONE WAY FOR THE INVESTIGATOR AND ANOTHER TO THE PERSON WHO CONSENTS

C Appendix

Computer Game played in the Game-Based Approach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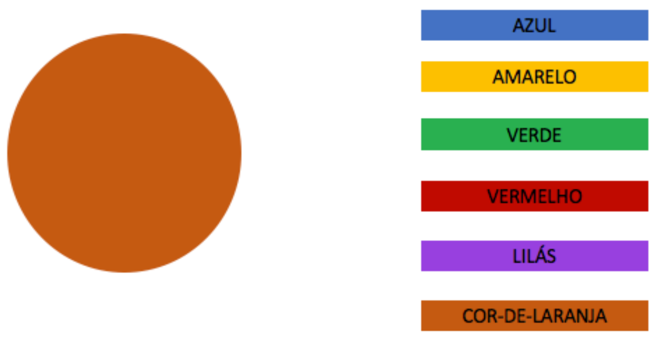
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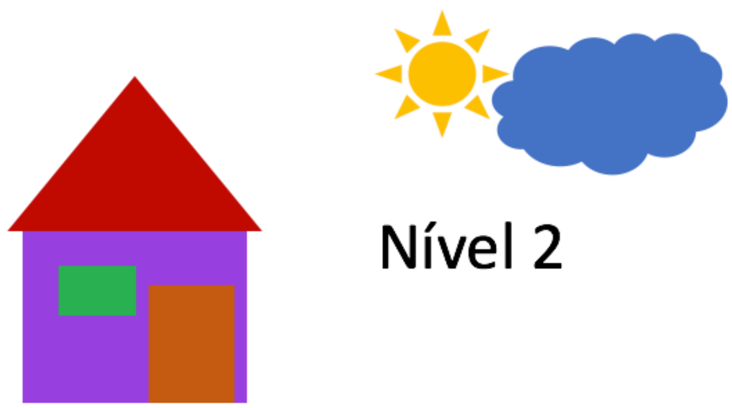
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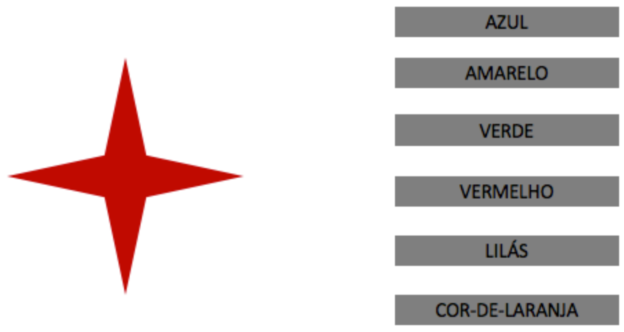
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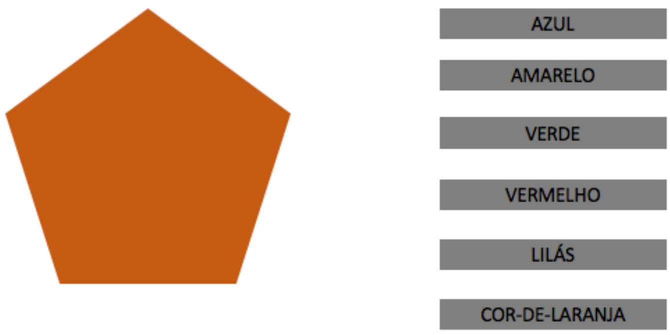
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