

UNIVERSIDADE DE CAXIAS DO SUL

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**BACHELOR FINAL PROJECT:
SOCIALY INTERACTIVE ROBOTS: AN EXPERIMENT ON THE ASSISTIVE
CONTEXT**

**Caxias do Sul
2017**

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Socially Interactive Robots: an experiment on the assistive context**

Bachelor final project to obtain the bachelor's degree in Computer Science at Universidade de Caxias do Sul.

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**Caxias do Sul
2017**

To my mom who has dedicated her life to see me accomplish what she was not able to.
To my sister for the very insightful and philosophical discussions.
And to all the visually impaired people who have inspired me through the whole project with
their joy and unique understanding of the world.

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Detective Del Spooner: I think you murdered him because he was teaching you to simulate emotions and things got out of control.

Sonny: I did not murder him.

Detective Del Spooner: But emotions don't seem like a very useful simulation for a robot.

Sonny: [getting angry] I did not murder him.

Detective Del Spooner: Hell, I don't want my toaster or my vacuum cleaner appearing emotional...

Sonny: [hitting table with his fists] I did not murder him!

Detective Del Spooner: [as Sonny observes the inflicted damage to the interrogation table] That one's called anger. Ever simulate anger before?

I, Robot (2004)

ABSTRACT

The Socially Assistive Robotics (SAR) field studies how robots can help humans through social rather than physical interaction. It may seem contrary to common sense expectation that physical robots can be used for social assistance, as one could just use software agents or other devices in order to do that. Researchers point out, however, that humans tend to attribute life-like characteristics to robots and to socially engage with them, as they are embodied agents that have enough biological-like motion or appearance aspects. In this case, people commonly engage with physical machines, projecting intentions, goals, and emotions to them. In this study we have investigated, through a short-term experiment, blind persons perceptions of a physically collocated robot compared to a regular computer in regard to functional and social aspects. Results show that, in general, participants preferred to interact with the robot, demonstrating interest and being more engaged. In addition, our findings suggest that the physical embodiment evokes a positive attitude from the blind persons towards the robot, even when the physical capabilities of the robot are not explored.

Keywords: social robots. human-robot interaction. socially interactive robots. socially assistive robotics. human perception of social robots.

RESUMO

O campo de Robótica Socialmente Assistiva (SAR) estuda como os robôs podem ajudar os seres humanos através de interações sociais ao invés de interações físicas. Pode parecer contrário à expectativa do senso comum de que os robôs físicos podem ser usados para assistência social, já que agentes de software ou outros dispositivos poderiam ser utilizados para fazer isso. Os pesquisadores apontam, no entanto, que os seres humanos tendem a atribuir características de vida aos robôs e se envolver socialmente com eles, pois são agentes incorporados que possuem aspectos de movimento ou aparência biológica semelhantes. Neste caso, as pessoas costumam se envolver com máquinas físicas, projetando intenções, objetivos e emoções nelas. Neste estudo, investigamos, através de um experimento de curto prazo, as percepções das pessoas cegas a respeito de um robô fisicamente localizado em comparação com um computador regular em relação aos aspectos funcionais e sociais. Os resultados mostram que, em geral, os participantes preferiram interagir com o robô, demonstrando interesse e mais comprometimento com a interação. Além disso, nossas descobertas sugerem que a personificação física evoca uma atitude positiva das pessoas cegas em relação ao robô, mesmo quando as capacidades físicas do robô não são exploradas.

Palavras-chave: robôs sociais. interação humano-robô. robô socialmente interativos. robôs socialmente assistivos. percepção humana de robôs sociais.

LIST OF FIGURES

1	JD and its main features.	38
2	Cozmo is a small robot focused on entertainment.	38
3	NAO interactive companion robot and its features.	39
4	UXA-90 and its components.	39
5	UXA-90 is able to mimic various human movements.	39
6	iRobot Create is a special version of the Roomba robot vacuum cleaner for researchers.	40
7	Ringo is a small insect-shaped robot.	41
8	Asimo executing one of the many tasks it is capable of.	41
9	PARO robot interacting with a patient with dementia.	42
10	Robovie-II during an experiment at a supermarket.	42
11	Kismet, the pioneer in social robots.	43
12	Aibo and its main features.	44
13	Jibo and its creator, Cynthia Breazeal.	44
14	Bandit and its creator, Maja Matarić, during a TEDTalk.	45
15	Torta et al. (2014) questionnaires.	61
16	The Godspeed questionnaires.	62
17	The E-Z Builder project used in the experiment.	67
18	The final version of the Microsoft Bing Text-to-Speech plugin.	67
19	The Bing Speech Recognition plugin settings with the button to edit the script.	68
20	The script editor of E-Z Builder.	69

LIST OF TABLES

1	General classifications used in the HRI area, covering the entire spectrum of interaction.	16
2	Relevant work in the HRI area.	19
3	Social robots and their general classification, based on the categories defined by Fong, Nourbakhsh and Dautenhahn (2003)	45
4	Comparison of robots.	64

LIST OF ACRONYMS

HRI	Human-Robot Interaction
SAR	Socially Assistive Robotics

CONTENTS

1 INTRODUCTION	12
1.1 HUMAN-ROBOT INTERACTION	13
1.1.1 Taxonomy	14
1.1.2 Application areas	18
1.1.3 Related work	18
1.2 OBJECTIVES	21
1.2.1 General Objective	21
1.2.2 Specific Objectives	21
1.3 STRUCTURE OF THE WORK	22
2 SOCIALLY INTERACTIVE ROBOTS	23
2.1 CLASSES OF SOCIAL ROBOTS	23
2.2 DESIGN APPROACHES	24
2.2.1 Biologically inspired	25
2.2.2 Functionally designed	25
2.3 DESIGN ISSUES	26
2.3.1 Embodiment and Morphology	26
2.3.2 Emotion	27
2.3.3 Dialog	28
2.3.4 Personality	28
2.3.5 Human-oriented perception	29
2.3.6 Other issues	30
2.4 DESIGN (OR INTERACTION) PATTERNS	31
3 APPLICATIONS OF SOCIAL ROBOTS	32
3.1 MAIN APPLICATIONS	32
3.1.1 Research	32
3.1.2 Entertainment	33
3.1.3 Education	33
3.1.4 Service and therapy	34
3.2 SOCIALLY ASSISTIVE ROBOTICS	35
3.2.1 Specific design issues	36
3.3 EXAMPLES OF SOCIAL ROBOTS	37
3.3.1 JD	37
3.3.2 Cozmo	37
3.3.3 NAO	38
3.3.4 UXA-90	38
3.3.5 iRobot Create	40
3.3.6 Ringo	40
3.3.7 Asimo	41
3.3.8 PARO	41
3.3.9 Robovie-II	42
3.3.10 Kismet	43
3.3.11 Aibo	43
3.3.12 Jibo	43
3.3.13 Bandit	44

4 HUMAN PERCEPTION OF SOCIAL ROBOTS	54
4.1 ATTITUDES TOWARDS ROBOTS	54
4.1.1 Effects of emotion	55
4.1.2 Effects of appearance and dialog	55
4.1.3 Effects of personality	55
4.1.4 Field studies on social robots	56
4.1.5 Human response to SAR	56
4.2 EVALUATING HRI	57
4.2.1 Metrics of evaluation	57
4.2.2 Human studies methods	59
5 EXPERIMENT	63
5.1 COMPARISON OF ROBOTS AVAILABLE FOR RESEARCH	63
5.1.1 Chosen robot	63
5.2 MOTIVATION	63
5.3 PROCEDURE	65
5.3.1 Evaluated metrics and results	66
5.4 FRAMEWORK	66
5.4.1 E-Z Builder	66
5.4.2 Microsoft Bing Text-to-Speech plugin	67
5.4.3 Scripts	68
6 CONCLUSION	70
6.1 WORK SYNTHESIS	70
REFERENCES	71
APPENDIX A – SURVEY OF RELEVANT ARTICLES	74
APPENDIX B – MAJA J MATARIĆ THOUGHT ON SAR FOR THE BLIND	80
APPENDIX C – JD PROGRAMMING SCRIPT	81
APPENDIX D – QUESTIONNAIRES BASED ON THE GODSPEED SERIES	85
APPENDIX E – ARTICLE SUBMITTED TO THE HRI CONFERENCE 2018	88

1 INTRODUCTION

Robotics is a topic that has been discussed for decades. It has been gaining a lot of strength in recent years due to the growing technological advances we are currently experiencing, which allows for a more advanced development of robotics techniques and accelerates research in the field. Defined by Merriam-Webster.com (2017, N/A) as the "technology that is used to design, build, and operate robots," robotics arouses curiosity and involves varied applications such as the use in industry, education, aiding the sick and elderly, and even on battlefields. Although some robots keep isolated from humans for jobs that do not involve any kind of interaction, as in some industries, most of these applications include some kind of interaction, which has been debated among scientists and researchers across an area known as *Human-Robot Interaction*, dedicated to understanding, designing, and evaluating robotic systems for use by or with humans (GOODRICH; SCHULTZ, 2007).

Several application areas are part of HRI. Goodrich and Schultz (2007) separate HRI into 6 main areas: *search and rescue, assistive and educational robots, entertainment, military and police, space exploration, unmanned air vehicles (UAVs) reconnaissance and unmanned underwater vehicles (UUVs) applications*. The general HRI area of *assistive robots* comprise a more in-depth study of social robots, although not all robots in this area have a social behavior. Social robots are defined as the ones to which human-robot social interaction is relevant (FONG; NOURBAKHSH; DAUTENHAHN, 2003), and the social robots that are also assistive comprehend the area as *Socially Assistive Robotics (SAR)*.

Thus, a socially assistive robot shares all the challenges that a social robot faces, and for the study of social robots to be valid, it is necessary to understand the patterns of interaction between humans and robots. Because it is a fairly new area, HRI in general still needs further study of interaction patterns, though some researchers have developed criteria and metrics to evaluate this interaction. In a survey carried out by Murphy and Schreckenghost (2013), 42 metrics were classified, although there is still no consensus about them. One of the most used work regarding metrics is that of Steinfeld et al. (2006), and within the various evaluation criteria proposed in his work we find 5 social metrics, namely: *interaction characteristics, persuasiveness, trust, engagement, and compliance*. More specific criteria regarding socially assistive robots are added by Tapus, Mataric and Scassellati (2007), namely *social success, impact on the user's care, impact on caregivers, and impact on the user's life*, and more general ones, like *autonomy, imitation and privacy*. In addition, Torta et al. (2014) uses *anxiety, social presence* and other metrics specific to robots that are behave socially and are also assistive.

These metrics were elaborated based on the many design issues and challenges faced by social robots, which include characteristics such as embodiment and morphology, emotion, dialog, personality and specific human-oriented perception issues, like people tracking and speech recognition. Understanding how to address these issues is crucial for the design of a robot and the way it interacts with humans, as every application will have its own specific needs (FONG;

NOURBAKSHI; DAUTENHAHN, 2003).

It is well known to the HRI community, as many studies show, that people tend to attribute human characteristics to machines, creating bonds, projecting intentions, goals, emotions, and engaging with them (MATARIĆ, 2013). One study by Sung et al. (2007) with the iRobot's Roomba™ vacuum cleaner robot shows that, in addition to monitoring and rescuing their vacuums in case of problems, participants from a forum (aimed at owners of Roombas) watch the work of their Roomba (some participants have more than five of these vacuum cleaners), and this causes them a sense of happiness. In addition, participants frequently use associations of everyday life to engage with the robot, often assigning personality, name, and gender to them. Finally, it was found that these participants give enough value to the vacuum cleaner to change the layout of their home so that the robot can work better and to recommend and lend them to other people so they can try it out. At the same time, they show great concern about how these people will take care of the robot. In addition to the findings of this study, there are reports of people whose Roombas broke and were sent to technical assistance with letters. One of them said, "please fix my Roomba because my Roomba's my friend. I don't want another Roomba, I want you to fix this one" (GOLDHILL, 2014, N/A).

The SAR researchers take advantage of the fact that people engage socially with robots, designing robots that help humans through social interaction rather than physical contact (MATARIĆ, 2007). One example is PARO, a robotic seal that is used in therapy, specially for the elderly. A recent study with people with dementia indicated that PARO is a social robot that is viable for use with people with mid to late-stage dementia and might have a role in improving their mood and social interaction (MOYLE et al., 2013).

Thus, the focus of this study is on understanding the relationship between humans and robots and the affective bonds that may be formed, as well as how that social interaction can help people with special needs. To validate behavior and interaction aspects observed in previous studies, an experiment was conducted aiming to analyze the design issues addressed in the area. Also, it evaluated a social robot through some of the metrics that other studies propose, linking concepts from different areas such as computer science, philosophy and psychology, in order to demonstrate what social characteristics a robot must have to be used with visually impaired users, and determining how this analysis of the human-robot relationship can be useful for future work.

1.1 HUMAN-ROBOT INTERACTION

Human-Robot Interaction (HRI) is "an area dedicated to understanding, designing, and evaluating robotic systems for use by or with humans" (GOODRICH; SCHULTZ, 2007, p. 204). By definition, interaction requires communication between humans and robots, which can take several forms that are largely influenced by whether the robot and the human are in close proximity to each other or not. Thus, this interaction can be separated into two general categories:

- **Remote interaction:** the human and the robot are not in the same place and can even be temporally apart, like the Mars Rovers that are separated from earth both in space and time. Remote interaction with mobile robots is frequently referred to as *teleoperation* or *supervisory control*, and remote interaction with a physical manipulator as *telemanipulation*.
- **Proximate interaction:** the human and the robot are situated in the same place, like service robots that may be in the same room as humans. When mobile robots are involved, it may take the form of a robot assistant and may include a physical interaction.

As the main topic of this work, *social interaction* involves social, emotive, and cognitive aspects of interaction, where humans and robots interact as peers or companions. Goodrich and Schultz (2007) emphasizes that social interactions with robots appear to be more classifiable as *proximate interaction* rather than remote, though we can have social interaction when referring to some robots under the remote collaboration category.

According to Tzafestas (2015), HRI is essentially different from standard human-computer interaction in several ways, as robots are complex, dynamic control systems, that demonstrate cognition and autonomy, and operate in modifying real-world environments. Further contrasts happen in the types of interaction (and their functions), the physical form of robots, the quantity of systems a human may be asked to interact with at the same time, and the situation where the collaborations happen.

The interaction between humans and robots is one of the most important capacities required for a smooth and beneficial co-habitation of people and robots. Robots need to work with the presence of people in conditions that are normally very similar to real world scenarios, and sometimes in the "wild" (real world), thus frequently requiring human abilities. For a robot to have the capacity to work proficiently in such genuine situations, both mechanical movement abilities, and great interfaces that guarantee legitimate human-robot social cooperation are required, as well as other aspects that could potentially benefit the interaction (TZAFESTAS, 2015). Because of this, HRI needs some general classification of these characteristics so that we can understand the robot's purpose and its role in the relationship with humans.

1.1.1 Taxonomy

HRI can differ in the complexity, scope and applications. Thus, throughout the years many classification (taxonomy) plans were suggested extending from industrial robots up to social robots. Many of these ideas came from the human-computer interaction area. Tzafestas (2015) provides us with 5 (five) different *categorization groups* based on the taxonomy proposed by various authors.

- **Greif (1988)** created two classes according to whether humans use the computer at the same time or at different times (not depending on others to be around at the same time);

- **Nickerson (1997)** adds the mode of communication used by collaborators (audio, visual, data, etc.) to the categories of Greif (1988);
- **Bartneck and Okada (2001)** created a general taxonomy in order to determine whether the robot is designed to help humans or to be used as a toy for entertainment; if it is non-autonomous, semi-autonomous, or fully autonomous; the dialog complexity where the robot can imitate humans or respond accordingly, and how similar to a human the robots is going to be;
- **Balch (2002)** puts together several HRI types to determine how long a task is needed; if synchronization is needed; the maximum time horizon for optimization; robot or object motion (or both), power, intra-team completion for resource sharing; whether the task can be accomplished by a single agent or requires multiple agents, and whether the system can fully or partially observe the world;
- **Breazeal (2004)** created a taxonomy with four interaction paradigms based on the mental model that, during the interaction with a robot, a human has of it, defining whether the robot is viewed as a tool, physically joined with the human (e.g., a robotic leg for a person's movement), as an avatar where humans project themselves through the robot, or as a social partner where the collaboration is seen by the human like associating with another creature that collaborate as a companion;
- **Yanco and Drury (2004)** created a general and more embracing classification of HRI, determining that the task should be specified at a high level (e.g., walking robot, aid for the blind, entertainment); if a failure can severely injure or kill its user; the appearance of the robot, as it influences peoples reactions; the ratio of people to robots and if when sharing interaction, humans would all agree with the same commands; interaction roles in which the human can act as supervisor, operator, teammate, programmer, and bystander; the proximity of humans and robots, operating in these modes: avoiding, passing, following, approaching, and touching; the synchronous or asynchronous use of the systems and whether humans and robots are collocated or non-collocated, and the autonomy level and amount of intervention that should have a sum of 100%;

The proposed taxonomies' topics can be summarized in categories, as seen in Table 1.

Table 1: General classifications used in the HRI area, covering the entire spectrum of interaction.

Author(s)	Name or topic	Categories
Greif (1988)	<i>Computer-supported cooperative work (CSCW)</i>	<ul style="list-style-type: none"> • Asynchronously • Synchronously
Nickerson (1997)	<i>Collaborative application taxonomy (CAT)</i>	<ul style="list-style-type: none"> • Asynchronously • Synchronously • Modal
Bartneck and Okada (2001)	General taxonomy focused on the role of the robot	<ul style="list-style-type: none"> • Toy-tool-scale • Level of autonomy scale • Reactive-dialog scale • Robot morphology scale
Balch (2002)	<i>Task and reward taxonomy (TRT)</i>	<ul style="list-style-type: none"> • Time • Performance measurement criteria • Subject of action • Resource constraints • Platform capabilities

Continued on next page

Table 1 – continued from previous page

Author(s)	Name or topic	Categories
Breazeal (2004)	Taxonomy based on interaction paradigms	<ul style="list-style-type: none"> ● Robot as a tool ● Robot as a cyborg extension ● Robot as avatar ● Robot as a social partner
Yanco and Drury (2004)	Very generic taxonomy	<ul style="list-style-type: none"> ● Task type ● Task criticality ● Robot appearance ● Ratio of people to robots ● Level of shared interaction ● Interaction roles ● Human-robot proximity ● Time-space ● Autonomy level/Amount of intervention

Source: Elaborated by the author.

Although most of these general definitions have some overlapping, they are very useful to classify the HRI and have very clear differences.

For social robots, some of the categories do not apply. For example, the *robot as a cyborg extension* paradigm under the work of Breazeal (2004) won't have any kind of social interaction (though some kind of interaction will be present), but the *robot as a social partner* category, defined under the same work, certainly encompasses socially interactive robots. Thus, this study focuses on the work of Breazeal (2004), in the specific paradigm of robots as social partners.

1.1.2 Application areas

HRI has many **application areas**. Goodrich and Schultz (2007) separate the field into six (6) main areas:

- Search and rescue;
- Assistive and educational robots;
- Entertainment;
- Military and police;
- Space exploration;
- Unmanned air vehicles (UAVs) reconnaissance and unmanned underwater vehicles (UUVs) applications;

The focus of this work, social robots, also has its own distinct application areas. The **assistive and educational robots** and **entertainment** areas comprise a more in-depth study of social robots than the others, and are expanded in Chapter 2.

1.1.3 Related work

Although work related to the study of the relationship between humans and robots were presented before 1990, the HRI area began to develop in the mid-1990s and early 2000s (GOODRICH; SCHULTZ, 2007). Numerous events occurred in this time frame, the main catalyst being a multidisciplinary approach, when researchers in robotics, cognitive science, human factors, natural language, psychology, and human-computer interaction began to gather at events recognizing the importance of working together.

Important conferences in the area are: *IEEE International Symposium on Robot & Human Interactive Communication (RoMan)*; *International Conference on Humanoid Robots*, created by IEEE/Robotics Society of Japan; *IEEE International Conference on Robotics and Automation (ICRA)*; *Human Factors and Ergonomics Society*; and more recently, launched in 2006, HRI got its own annual conference to address the multidisciplinary aspects involved, entitled *ACM International Conference on Human–Robot Interaction*. Another important conference, more specific for the Social Robotics field, is the *International Conference on Social Robotics (ICSR)*.

According to Goodrich and Schultz (2007), another major influence on the evolution of HRI has been the competitions involving robots, the two largest being the *AAAI Robotics Competition and Exhibition* and the *Robocup Search and Rescue competition*.

In Brazil, literature is scarce in the HRI area. A notable Brazilian work is that of Vasconcelos et al. (2015), in which a methodology is proposed to dynamically adapt the behavior of the robot

during its navigation considering the possibility of finding humans in the environment. Foreign literature is extensive and, therefore, has a greater weight as a reference for this project.

Articles with the most relevant authors in the area are listed in Table 2. For the selection of these and other articles used in this research, the origin of the data (mostly from the cited conferences), the year of publication and mainly the number of citations obtained by the work (see A) were used as a criterion of relevance.

Table 2: Relevant work in the HRI area.

Authors	Topic	Findings	Methods	Tools
Goodrich, M.A.; Schultz, A.C	HRI review (<i>survey</i>)	Presents a review of HRI, addressing unified issues in the area, identifying key topics, and discussing challenges that should shape the area in the near future, such as human, robotic, cognitive, psychological, and design factors.	Historical review	-
Fong, T.; Nourbakhsh, I.; Dautenhahn, K.	HRI review (<i>survey</i>) of social robots	Introduce a review of socially interactive robots, presenting methods and patterns of interaction and discussing the context where social robots are inserted, relating the topic to other areas of knowledge and discussing the impacts of these robots on humans.	Historical review	-

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Table 2 — continuation of previous page.

Authors	Topic	Findings	Methods	Tools
Kahn Jr., P. H.; Kanda, T.; Ishiguro, H.; Freier, N. G.; Severson, R. L.; Gill, B. T.; Ruckert, J. H.; Shen, S.	Children's response to the au- tonomy of social humanoid robots	Discusses how the moral and social re- lationship with future personified robots can be substantial and meaningful and how personified robots can emerge as a unique ontological category in the future.	Research with exper- iment	Robovie Robot and Wizard of Oz Techniques
Steinfeld, A.; Fong, T.; Kaber, D.; Lewis, M.; Scholtz, J.; Schultz, A.; Goodrich, M.	HRI evalua- tion metrics	Describes com- mon metrics for task-oriented HRI, identifying factors to be taken into account and describing the research framework, including a summary with specific task metrics that are al- ready in use and other suggested metrics for standardization.	Comparative research	-
Breazeal, C.	Expressions and Emo- tions of Humanoid Sociable Robots	Describes the role of emotional behav- ior and expressions regulating social interaction between humans and anthro- pomorphic expressive robots, in both com- munication and teaching scenarios.	Research with exper- iment	Kismet robot

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Table 2 — continuation of previous page.

Authors	Topic	Findings	Methods	Tools
Mataric, M. J.; Feil-Seifer, D.	Definition of the field of socially assistive robotics	Defines the research area of socially assistive robotics, with a focus on assisting people through social interaction instead of physical interaction, summarizing and classifying social assistive research projects as well as discussing challenges and opportunities that are specific to this field.	Research	-

1.2 OBJECTIVES

1.2.1 General Objective

Understand the characteristics of the relationship between humans and robots through previous studies and develop an experiment in order to compare with recent studies.

1.2.2 Specific Objectives

In order to achieve the general objective, the following specific objectives will be followed:

- Search the studies conducted in the HRI area, from the oldest to the most recent, in order to observe changes and patterns between HRI over the years and to identify criteria to evaluate the quality of the interactions;
- Define and classify the different aspects of the interaction between humans and robots, taking into account the public that uses these robots and the purpose of the interaction;
- Identify what desirable behaviors a robot should have for each type of interaction, selecting social patterns to be validated, focusing on assistive social robots;

- Through an experiment with a programmable robot, observe the selected patterns and human responses to the behavior of the robot.

1.3 STRUCTURE OF THE WORK

This work starts with a general definition of HRI in Chapter 1, its taxonomy, applications and related work. Chapter 2 introduces the socially interactive robots, its classes, design issues and patterns, and describes their importance and current trends, as well as expanding the field of socially assistive robotics. Chapter 3 defines the application areas and examples of social robots. In Chapter 4, the attitudes of humans towards robots are described, focusing on emotion, appearance, dialog and personality. It also identifies effects of robot's characteristics on humans, and discusses how we can evaluate HRI, as well as how human studies should be conducted in the area. Chapter 5 summarizes the experiment executed to validate this research, including a description of the framework used. Finally, Chapter 6 concludes the study. Main results from this study are described in an article (Appendix E) that was submitted to the 13th Annual ACM/IEEE International Conference on Human Robot Interaction.

2 SOCIALLY INTERACTIVE ROBOTS

Broadly and generically, social robots are defined by Fong, Nourbakhsh and Dautenhahn (2003, pg. 2) as

embodied agents that are part of a heterogeneous group: a society of robots or humans. They are able to recognize each other and engage in social interactions, they possess histories (perceive and interpret the world in terms of their own experience), and they explicitly communicate with and learn from each other.

This definition, though very generic, opens up a discussion about all the aspects involved in the HRI with social robots. As Fong, Nourbakhsh and Dautenhahn (2003) state, socially interactive robots are those for which the social interaction between humans and robots is important. Understanding this interaction allows us to build better robots and to aim at the right direction, making the relationship between human and robot as close as possible to the human-human relationship when necessary and removing all traces of human-like characteristics when that is the case, as well as keeping a balance when only some traces of human characteristics are needed.

As seen in Chapter 1, the HRI area has many application areas. Although socially interactive robots can be found within all of them, some areas have robots whose focus is explicitly on the social interaction, like *assistive and educational robots* and *entertainment*. Thus, social robots isn't a sub-area of HRI, but its study coexists and both areas complement each other. The socially interactive robots field, however, does have some sub-areas, like the assistive robots, that intersect with the studies of HRI. Therefore, this intersection of **assistive robotics** and **socially interactive robotics** defines the *socially assistive robotics* area (FEIL-SEIFER; MATARIC, 2005).

An important concept for the study of social HRI is the idea of *social cognition*, a sub-topic of social psychology that, according to Cherry (2016, N/A), "focuses on how people process, store, and apply information about other people and social situations." It concentrates on the role that cognitive processes play in our social interactions. The way we consider others assumes a noteworthy part in the way we think, feel, and associate with the world around us.

Social robots, or socially interactive robots, can be classified depending on the social model used by people when observing and interacting with autonomous intelligent robots (BREAZEAL, 2002a).

2.1 CLASSES OF SOCIAL ROBOTS

Breazeal (2002a) defines 4 social robot classes:

- **Socially evocative:** robots that depend on the human inclination to anthropomorphize them, inducing emotions when people care and attribute social responsiveness to them, though the robot won't correspond to the humans feelings. E.g., toys and pets used for entertainment.
- **Social interface:** robots that give a "natural" interface by using human-like social cues and communication modalities. Social behavior is only shown at the interface, therefore social cognition models aren't very significant. E. g., avatars.
- **Socially receptive:** robots that are socially passive yet profit by collaboration (e.g. learning aptitudes by impersonation). More profound models of human social skills are required than with social interface robots, although their application is practically the same.
- **Sociable:** robots that pro-actively connect with people to fulfill inside social points (drives, feelings, and so on). These robots require profound models of social cognition. E. g., humanoid robots used in research.

Fong, Nourbakhsh and Dautenhahn (2003) add three other classes:

- **Socially situated:** robots that are encompassed by a social situation that they comprehend and respond to. Socially situated robots must have the capacity to recognize other social agents and different objects in the environment.
- **Socially embedded :** robots that are arranged in a social situation and associate with different agents and people, combining with their social environment, and at least partly aware of human interactional structures, like knowing when to start and finish a turn in a conversation.
- **Socially intelligent:** robots that show parts of human style social intelligence, supported by profound models of human cognition and social ability.

2.2 DESIGN APPROACHES

According to Fong, Nourbakhsh and Dautenhahn (2003), as humans are experts in social interaction, we can expect that people will find the interaction enjoyable, feeling empowered and competent, if technology corresponds to their expectations. That's why many researchers focus on developing anthropomorphic (or zoomorphic) robots, so that they seem more "human-like" or "creature-like" and allow for an interaction humans are used to. Therefore, many robots have been created with characteristics such as speech recognition, faces and other features and capacities that will make the interaction seem closer to that of humans.

That leads us to two primary design approaches, biologically inspired and functionally designed.

2.2.1 Biologically inspired

In the biologically inspired design approach, designers try to create robots that resemble or simulate the social behavior or intelligence of living entities. These designs are based on theories drawn from natural and social sciences, including anthropology, cognitive science, developmental psychology, ethology, sociology, structure of interaction, and theory of mind (FONG; NOURBAKHS; DAUTENHAHN, 2003).

The four techniques most often used in biologically inspired design are as follows:

- *Ethology*: alludes to the observational investigation of creatures in their normal setting, that analyzes human behavior and social organization from a biological perspective, aiming to design robots that display some instinctive behavior keeping in mind the end goal to appear life-like.
- *Structure of interaction*: study of interactional structure (for example, cooperation) can help center design of perception and cognition systems by recognizing key interaction patterns.
- *Theory of mind*: refers to those social aptitudes that enable people to effectively give convictions, objectives, discernments, emotions, and yearnings to themselves and others. One of the basic precursors to these abilities is joint (or shared) attention: the capacity to specifically take care of a question of mutual interest. Joint attention can help plan, by giving rules to perceiving and creating social behaviors such as gaze direction, pointing gestures, etc.
- *Developmental psychology*: has been referred to as a compelling component for designing robots that take part in regular social trades. The perceptual and behavioral characteristics of some robots, for example, are motivated by the social development of human infants.

2.2.2 Functionally designed

The three techniques most often used in functional design are as follows:

- *Human–Computer Interaction (HCI) design*: robots are progressively being produced using HCI procedures, including cognitive modeling, contextual inquiry, heuristic evaluation, and empirical user testing. User studies are conducted, usually while development is taking place, so that the user’s activities can be better perceived and to determine the interface (or framework) usability characteristics.
- *Systems engineering*: includes the top-down development of a frameworks’ functional and physical necessities from an essential set of goals. A basic feature of system engineering is that it gives importance only to the design of critical-path system components,

like mobile robots that are intended to help the elderly in every day living. Since these robots work in a very organized space, their design focuses on a group of task-based behaviors, like autonomous navigation, instead of wide social interaction.

- *Iterative design*: iterative (or sequential) design, is the process toward changing a design through a sequence of test and update cycles. It can be a successful technique, especially when a framework or its target environment are hard to model analytically.

2.3 DESIGN ISSUES

Whether a robot system is socially interactive or not, they must all address numerous common design problems (FONG; NOURBAKHSH; DAUTENHAHN, 2003), like cognition (decision making), perception (navigation, sensing of the environment), action (mobility), the HRI itself (user interface, feedback) and architecture (system, control). Nevertheless, socially interactive robots should add the issues that social interaction impose.

Breazeal (2002b) and Fong, Nourbakhsh and Dautenhahn (2003) define some issues that are special to the socially interactive robots. Four design issues that are very general are:

Natural robot and human interaction: people and robots ought to convey as associates who know each other well, e. g., performers playing a duet. To accomplish this, the robot must show credible conduct: it must build up proper social expectations, managing social communication (utilizing dialog and activity), and following social convention and standards.

Readable social cues: a socially interactive robot must send signs to the human so that it gives feedback of its inside state and it admits human to connect in a simple, straightforward way. Since robots are built, they have restricted channels and ability with regards to emotional expression, that can be facial expression, body and pointer gesturing, and vocalization (both speech and sound).

Real-time performance: socially interactive robots must work at human interaction rates. Therefore, a robot needs to, at the same time, show skilled behavior, bring on attention and purposefulness, and deal with social interaction.

The following sections describe more specific design issues that have significant impact on the HRI itself. They are derived from the general issues above, and can be used to classify and evaluate robots and the interaction they have with humans.

2.3.1 Embodiment and Morphology

Embodiment is defined by Dautenhahn, Ogden and Quick (2002, pg. 8) as “that which establishes a basis for structural coupling by creating the potential for mutual perturbation between system and environment”. Thus, embodiment is basically the connection between a system and its environment. Additionally, it implies that social robots don’t really require a physical body. For instance, conversational agents might be considered as embodied as a robot with very lim-

ited actuation. Therefore, it allows us to measure embodiment. For example, one may quantify it in terms of the complexity of the relationship amongst robot and environment. Hence, all robots are embodied, yet some are more than others, and the more a social robot can interfere in its environment and be perturbed by it, the more it is embodied (FONG; NOURBAKHSH; DAUTENHAHN, 2003).

The *morphology* (physical appearance) of social robots powerfully impacts their interaction with people. For instance, humans might face a dog-like robot differently than an anthropomorphic one. Specifically, the nature or peculiarity of the morphology of a robot may strongly affect its acceptability, believability, desirability, and expressiveness (TZAFESTAS, 2015). The shape and structure of a robot is essential since it builds up social expectations.

Physical appearance determines collaboration. A robot that looks like a dog will be dealt with in a different way than one which is anthropomorphic. In addition, the relative closeness of a robot's morphology can have significant impacts on its accessibility, desirability, and expressiveness. The decision of a given form may likewise limit the human capacity to collaborate with the robot.

Social robots as embodied agents can be classified in four broad categories (FONG; NOURBAKHSH; DAUTENHAHN, 2003):

- **Anthropomorphic:** robots to which we can attribute human characteristics (structurally and functionally similar to a human);
- **Zoomorphic:** robots having creature-like characteristics;
- **Caricatured:** robots with exaggerated distinctive or unusual features, producing comic effect or even providing a point on which people can focus their attention on;
- **Functional:** robots with physical features and design guided strictly by operational objectives, reflecting the tasks it must perform;

2.3.2 Emotion

As Fong, Nourbakhsh and Dautenhahn (2003) states, emotions have a considerable function in human behavior, communication and social interaction. It affects cognitive processes, specially problem solving and decision making, controls action, and shapes dialog. Furthermore, much of emotion is physiological and relies on embodiment.

Social robots can show emotions in different ways, and Fong, Nourbakhsh and Dautenhahn (2003) present five ways in which the robots can express emotions:

- **Artificial Emotions:** robots might generate artificial emotions in order to establish convincing HRI, helping the user (through the robot's feedback) to acknowledge the robot's internal state and aims.

- **Emotions as control mechanism:** robots can have computational models of emotions that mimic animal survival instincts, such as escape from danger, look for food, etc, and that can be used to decide control priority between various behavior models, to organize planning, and to trigger learning and adjustment, especially when the environment is obscure or hard to anticipate.
- **Emotional Speech:** robots can express emotion through speech, having loudness, pitch (level, variation, range), and prosody as the primary factors that control the emotional content of speech.
- **Facial Expression:** robots usually don't have life-like expressive behavior on their faces, reflecting constraints of mechatronic design and control, though facial expressions could potentially increase the quality of the interaction between humans and robots.
- **Body Language:** over 90% of gestures occur during speech and provide unnecessary information in human-human interaction. However, people see all motor actions to be semantically rich, regardless of whether or not they were really expected to be, what makes body language important for HRI.

2.3.3 Dialog

According to Fong, Nourbakhsh and Dautenhahn (2003), "dialog is a joint process of communication. It involves sharing of information (data, symbols, context) and control between two (or more) parties." Dialog is, with no doubt, an important part of the interaction between humans and robots, and are classified by Fong, Nourbakhsh and Dautenhahn (2003) in three categories:

- **Low-level:** robots have very simple language skills, sometimes synthetic.
- **Non-verbal:** robots can use their actions to communicate, including body positioning, gesturing, and other physical action.
- **Natural language** - robots use language in a way as close as possible to that of the human it is interacting with, depending on the context of the situation (social and cultural features).

2.3.4 Personality

In psychological terms, personality is the arrangement of characteristic qualities that, put together, differentiate individuals (FONG; NOURBAKHSH; DAUTENHAHN, 2003). In order to engage and interact with humans, robots should show some signs of personality. Many questions are addressed regarding personality in robots, like "is it beneficial to encourage a

specific type of interaction (e.g., infant-caregiver)?", or "should the robot have a designed or learned personality?". With those questions in mind, Fong, Nourbakhsh and Dautenhahn (2003) classify social robots in 5 common personality types:

- **Tool-like:** robots that operate as "smart devices," performing services and tasks on command.
- **Pet or creature:** robots that have creature-like characteristics, normally used for entertainment (usually associated with the robots under the *zoomorphic* embodiment type).
- **Cartoon:** robots that exhibit caricatured personalities, such as seen in animation (usually associated with the robots under the *caricatured* embodiment type).
- **Artificial being:** robots inspired by literature and film, primarily science fiction, inclined to display artificial characteristics.
- **Human-like:** robots are often designed to show human personality attributes. The level of human personality the robot has (or seems to have) depends on its use.

2.3.5 Human-oriented perception

To communicate purposefully with people, social robots must have the capacity to see the world as people do, i.e., detecting and deciphering the same experiences that people do. A socially interactive robot should efficiently perceive and decipher human action and behavior. This incorporates detecting and recognizing gestures, perceiving motions, observing and classifying actions, recognizing intent and social cues, and measuring the human's feedback. In this way, we can classify the characteristics social robots should have in 4 categories, regarding the human-oriented perception (FONG; NOURBAKHS; DAUTENHAHN, 2003):

- **People tracking:** robots can track people and take into account the presence of obstructions, inconsistent illumination, moving cameras, and varying background.
- **Speech recognition:** robots might need to perform speaker tracking, dialog management, or emotion analysis depending on what information it requires.
- **Gesture recognition:** robots could potentially increase the quality of the interaction if they could identify gestures, though that is a complex task that involves motion modeling and analysis, pattern recognition, and machine learning.
- **Facial perception:** robots can have face detection, face and facial expression recognition, and gaze tracking.

2.3.6 Other issues

According to Fong, Nourbakhsh and Dautenhahn (2003), keeping in mind the end goal to associate with individuals in a human-like way, socially interactive robots must comprehend the complexity of normal human social behavior. Identifying and perceiving human activity and correspondence it's a good way to start an interaction. More essential, nevertheless, is having the capacity to translate and respond to human behavior. A key instrument for performing this is **user modeling**.

There are many kinds of user models: cognitive, emotional, attentional, and so forth. A user model usually contains an arrangement of properties that identify a user, or group, of users. Models might be static or dynamic (adjusted or learned). Information about users might be obtained explicitly (through questioning) or implicitly (inferring through observation) (FONG; NOURBAKHSH; DAUTENHAHN, 2003).

Another issue that can be addressed is the **socially situated learning**, where an individual communicates with his social environment to get new abilities. People and some animals (e.g., primates) learn through a diverse range of strategies including direct care, observational conditioning, and imitation (FONG; NOURBAKHSH; DAUTENHAHN, 2003).

We can classify the way robots learn in 2 main ways:

- *Social learning*: for social robots, learning is used for exchanging abilities, tasks, and information. Learning is important as the knowledge of the instructor and the robot might be different altogether. Furthermore, in view of contrasts in detection and perception, the instructor and the robot may have very distinctive perspectives of the world. Along these lines, learning is regularly fundamental for enhancing perception, encouraging interaction, and sharing knowledge.
- *Imitation*: robots should have many perceptual, cognitive, and motor capabilities in order to be able to imitate (or learn from imitation), so researchers frequently alter the environment or situation to make the problem manageable. This is a very open topic in the HRI research, and questions like "how does the robot know when to imitate?" and "how does the robot know what to imitate?" still need to be addressed.

Another general design issue is that of **intentionality**. Fong, Nourbakhsh and Dautenhahn (2003) state that for a robot to connect socially, it needs to demonstrate that it's deliberate (even if not naturally). For instance, a robot could show goal-directed behaviors, or it could demonstrate attentional capacity. If it does so, then the human will believe the robot is acting in a rational way. Therefore, a social robot could show intentionality through two main ways:

- *Attention*: a robot could identify relevant objects in the scene, direct its sensors towards an object, performs gaze following, use gestures such as head nods in order to indicate the object, and keep its focus on the selected object in order to show its intentions.

- *Expression*: robots' motor actions could indicate their intentions, as well as facial expressions and speech.

2.4 DESIGN (OR INTERACTION) PATTERNS

A good way to identify the design issues addressed is to separate the interaction in "phases." Although this is still a new approach, it has been gaining a lot of attention from researchers in the area. While trying to standardize the interaction between humans and robots, Kahn et al. (2008) created 9 initial design patterns. They are intended to encompass the whole process of interaction and are named according to the phase they describe:

- Initial Introduction;
- Directing Other's Activity;
- Walking in Motion Together;
- Sharing Personal Interests and History;
- Pro-social Request;
- Recovery From Mistakes;
- Reciprocal Turn Taking in Game Context;
- Physical Intimacy;
- Claiming Unfair Treatment or Wrongful Harm;

These are just initial patterns and the authors encourage researchers to create more and to combine the existing ones, as they are mostly intended to characterize the "interactional" aspects of humans and their physical or social world. The author's intention is to use these patterns to better evaluate the interaction between humans and robots, identifying key behaviors in each step of the interaction process.

3 APPLICATIONS OF SOCIAL ROBOTS

As stated in Chapter 1, Goodrich and Schultz (2007) separate the HRI area in 5 main areas. From those, *assistive and educational robots* and *entertainment* can be viewed as the two in which social robots are more present, even though not all of the robots under these two categories interact socially and some robots from other categories might cooperate with humans in a way that is closer to that of social robots.

To the ones defined by Goodrich and Schultz (2007), we can add some application areas focused on social robots, as described by Fong, Nourbakhsh and Dautenhahn (2003): *robots as test subjects (research)*, *service*, *therapy*, and *anthropomorphic*.

The following sections describe some of these applications and the specific area of *socially assistive robotics*.

3.1 MAIN APPLICATIONS

3.1.1 Research

According to Fong, Nourbakhsh and Dautenhahn (2003), many researchers have been investigating how social robots can serve as experimental test subjects, as it is sometimes very hard to evaluate models of social and biological development in natural settings. Ethical concerns, complexities on implementing tests, and challenges separating hypothesized variables regularly make experimental evidence difficult to get.

Some specific uses of *social robots as test subjects* are:

- **Social development:** as a way to examine theories of social development, focusing on confirming, or refuting, allegations of how children develop in social learning skills (e. g. imitation, joint attention).
- **Social interaction:** as a way to examine theories that identify how interaction in a social context influences cognition, exploring communication and how social interaction provides a basis for how words (symbols) get their meanings.
- **Emotion, attachment and personality:** to analyze and validate many theories of individual behavior and how emotional behaviors evolve through long-term physical contact and interaction. Some studies have been conducted showing that when a human and a pet robot interact, they commonly inspire and influence each other, and as an effect of this interaction, humans can acquire the same attachment to the robot as to a real pet, particularly if the relationship happens over the long-term (FONG; NOURBAKHSH; DAUTENHAHN, 2003).

3.1.2 Entertainment

Several limits guide the commercially viable robotic interests in the toy and entertainment markets. An entertaining robot must reach a maximum of entertainment appraisal at a minimum of cost. The toy market usually applies design principles based on the "play-pattern" to the problem of toy-human interaction. Designers consider a limited set of ways in which the user is expected to interact with the toy, which is then designed with the explicit objective of enabling the desired list of play patterns (FONG; NOURBAKHS; DAUTENHAHN, 2003).

Some classifications of entertainment social robots are:

- **Animatronic children's dolls:** robots in which multiple sensors and processes are active at once. These processes can mix in many of ways to result in physical expressions and vocalized sounds.
- **Mobile social companions - quadruped and wheeled personal robots:** social robots that should reach enough independence to work well both while it is direct manipulated by the human or in times of passive human observation. Frequently designed after the social condition filled by domestic pets, they usually show some level of mobility, which is important for such companion robots as it demonstrates its personal autonomy. The Sony AIBO (see 3.3.11) was the pioneer of the commercially available quadruped companion robots and Cozmo (see 3.3.2) is one of the most technologically advanced entertainment social robots available.
- **Interactive goal-directed tools:** robots with a goal that surpasses that of engaging and entertaining the user. They can be more sophisticated and similar to therapy robots, like PARO.

3.1.3 Education

The function of robotic technologies in education is a wide subject. From the first Lego devices, teachers have been encouraged to incorporate robotic centered exercises for pedagogic purposes. Six noteworthy robotics competitions worldwide for secondary level students include *Robot Sumo*, *Botball*, *US First*, *MicroMouse*, *Firefighters*, and *RoboCup Soccer* (FONG; NOURBAKHS; DAUTENHAHN, 2003).

- **Robots as the educational focus** - the outcome of the study of robotics in the classroom are many, but common themes include: *interest in science and engineering*, especially for younger students that get more interested for science and technology fields while using/studying robots; *empowerment towards technology*, as studies show that students who have low technological self-esteem usually finish a course on robotics feeling technologically empowered; *teamwork*, as robotics' projects allow for interdisciplinary integration

opportunities; *problem-solving techniques*, as studying robot diagnosis and debugging enhances the skills of general problem-solving; *research and integration skills*, as students engaging on robotic creations should demonstrate the capacity to research the diverse knowledge frontier of the field and combine information across multiple areas: mathematics, physics, cognitive psychology, artificial intelligence and so forth;

- **Robots as educational collaborators** - more specific to social robots, where they can be part of the learning system. Students are not in the position of altering robot behavior nor its appearance. Instead, the robot can be a peer, companion, or collaborator in a larger educational project. Social robots are especially appropriate to occupy such a role, as robots continue to be unique and different. Thus, there is practically no established background preconception when it comes to the expected behavior of a robot tutor, and robots are able to easily catch the initial attention of students and hold that enthusiasm over some time. When contrasted to a software agent, the physical robot artifact shows not just far more elevated amounts of attention-grabbing, but also has a functionally helpful physical presence.

3.1.4 Service and therapy

Social robots can be designed and tested for a task-oriented mission. These robots find social interaction as beneficial for various reasons, one of them being usability, as social engagement like spoken dialog and gestures might help the robot to be easier to use for the beginner and also more efficient to use for the expert (FONG; NOURBAKHS; DAUTENHAHN, 2003). In addition, social interaction can be designed to make humans more comfortable while sharing a space with the robot.

- **Robots as assistants:** social robots can be assistants to humans in various ways, like aiding the elderly at home and preventing them from having to move to managed care facilities for months or even years. This help comes in many forms, like reminding them to use the restroom, eat, and turn on the television for a favorite show, for example. This classification is usually referred to as socially assistive robotics and is expanded in section 3.2.
- **Robots as collaborators:** social robots can become partners in achieving objectives, while recognizing their limitations and asking for help as needed. The connection between human and robot in this collaboration model is many-to-many. Four key qualities a collaborator robot must have in order to interact with teams are: enough *self-awareness* to recognize its limitations; being *self-reliant*, saving itself and avoiding the danger it may face; having *dialog competence*; and being *adaptive*, collaborating with all of the human resources in the team.

- **Short-term public interaction robots:** social robots can have short-term interactions in many different situations, and because of the nature of this kind of interaction, three characteristics are important to the success of these robots: include a *focal point*, serving as a clear focus of attention for the human; *communicate emotional state* to the visitors so that it gets the public attention to a determined subject; and have the capacity to *adapt its human interaction parameters* using information from the results of past interactions.

Robots are progressively being used in **therapy** and rehabilitation. Robotic wheelchairs allow some physically disabled people to have some of their mobility back in everyday situations. Physical contact, if joined with interactivity, can have a constructive effect on individuals, including calming, relaxation, stimulation, feelings of companionship and other emotional and physiological effects (FONG; NOURBAKSH; DAUTENHAHN, 2003). Benefiting from these effects, PARO (see 3.3.8), a robotic seal pup, imitates behavior characteristics and appearance of a baby harp seal.

(FONG; NOURBAKSH; DAUTENHAHN, 2003) also emphasizes that various methodological issues still need to be addressed when it comes to robots being used as assistants and in therapy, specially the developing and application of proper evaluation techniques, which must prove that robots truly have an effect and can make a difference compared to different methods of therapy and education, although much work has been done showing promising results (MATARIĆ, 2013).

3.2 SOCIALLY ASSISTIVE ROBOTICS

According to Feil-Seifer and Mataric (2005, pg, 465), socially assistive robotics (SAR) "is the intersection of **assistive robotics** and **socially interactive robotics**," sharing with assistive robotics the objectives to give assistance to humans, but defining that the assistance happens through social interaction.

The challenge of this area is to help people through social interaction instead of physical contact. SAR puts together HRI and assistive robotics, presenting a whole new series of research challenges, as researchers attempt to comprehend how robots can interact with people so that it can help effectively and measurably in the hard processes of recovery, rehabilitation, socialization, training, and education (MATARIĆ, 2007).

Matarić (2007) also says that it may seem contrary to intuition or to common-sense expectation that physical robots can be used for social assistance, as one could use software agents or other devices in order to do that. She points out, however, that humans tend to attribute life-like characteristics to machines and to socially engage with them, especially robots, as they are embodied agents that have sufficient aspects of biological-like motion or appearance. People cannot help but act on engaging with physical machines, projecting intentions, goals, and emotions to them.

Specific design issues are addressed on the SAR field, complementing those of general HRI,

in order to give robots particular characteristics, as they need to be both *useful* and *engaging*. In addition, Feil-Seifer, Skinner and Matarić (2007) state that robots that are socially assistive have the goal to provide the services that a human caregiver is unable to provide as one of their main uses, as well as filling the need for skilled workers, instead of trying to replace them.

3.2.1 Specific design issues

To the design issues proposed in 2.3, Tapus, Mataric and Scassellati (2007) add the following with a focus in SAR:

- **Empathy:** although very difficult to measure, empathy is particularly relevant to SAR because in patient-centered therapy it plays a very important role, as it suggests a joint comprehension of feelings. As studies show that patients recover faster if they receive empathy from their therapist, patient satisfaction and motivation to get better can be enhanced. Although machines cannot feel empathy, it is possible to design robots that show some signs of it. For a robot to emulate empathy, recognition of the user's emotional state should be one of the robot's capacities, along with communicating with people, displaying emotion, and so forth. As people experience and express emotions to communicate to others, a robot should appear to understand others' emotions and behave accordingly.
- **Engagement:** a robot should be aware of human presence and know when humans want to interact. As a way to establish and maintain the interaction with the human, a robot must be able to get attention to itself, either by eye contact or gaze tracking, while maintaining a certain distance, as well as using verbal and nonverbal communication.
- **Adaptation:** as SAR deals with vulnerable people, a robot should be capable of carefully considering user's needs and disabilities, learning from the user and adapting its capacities to the user's personality, moods, and preferences, providing a customized interaction.
- **Transfer:** for many socially assistive devices, it is desirable that the user gets to a point where they can use what they learn with the system in their everyday lives. A child with autism, for example, should be able to apply the skills he/she learned with the robot in interactions with friends and family. From various perspectives, skill and behavior transfer is the most important metric of accomplishment for some sorts of socially assistive robots.

In addition to these issues, Feil-Seifer and Mataric (2005) add the following topics as important matters to SAR:

- **User Populations:** SAR can reach many kinds of users, varying in age and needs. Some populations include the *elderly*, *individual with physical impairments*, *recovering patient individuals*, *individuals with cognitive disorders*, and *students*.

- **Task Examples:** the robot's task is guided by the users' needs, and can include *tutoring*, *physical therapy*, *daily life assistance*, and *emotional expression*.
- **Sophistication of Interaction:** SAR interactions change in type and sophistication, and emotion classification usually describes how the robot interacts with a human, but does not define the interaction by the human user. In SAR, *speech*, *gestures*, and *direct input* (such as a mouse or a touchscreen) are the most commonly and preferred interactive methods employed, while physical interaction with the robot itself is usually not used, unless necessary based on the nature of some users' conditions.
- **Role of the Assistive Robot:** SAR have acted as caregivers with doctors, nurses, and physical therapists. They have been used in treatments for children dealing with grief, as social mediators for children with autism, companions in nursing homes and primary schools. Effectively characterizing the function of the robot in these interactions is vital for developing its appearance and interaction methods. The role might be characterized by the activity the robot is helping with and the users it is working with, and by the impression it gives through its visual characteristics and behavior. For instance, a hospital robot may act like a nurse or a medical instrument based on the assignment and the type of interaction.

3.3 EXAMPLES OF SOCIAL ROBOTS

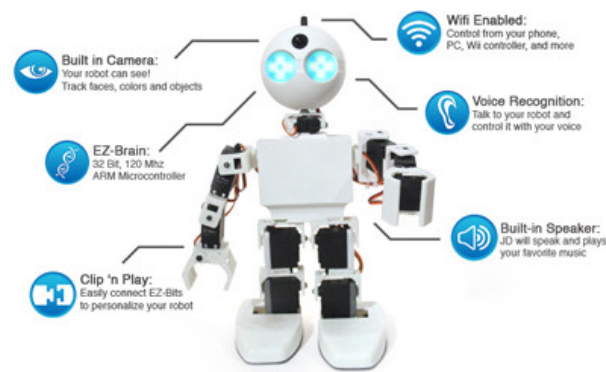
3.3.1 JD

JD is a humanoid robot developed by the Canadian company E-Z robots, which measures about 30cm in height and has several characteristics aimed at research and education. It includes facial recognition, color and movement, as well as being able to walk and dance. It is also possible to customize the robot with purchased parts (called ez-bits) that allow to give the robot practically any form (JD HUMANOID, 2017). The main features are pointed out in Figure 1.

3.3.2 Cozmo

Cozmo is a small robot developed by the American company Anki. Focused on entertainment, Cozmo has what the creators call unique personality that develops as the interaction grows. Cozmo has some sensors, such as edge detection, recognizes faces and emits some sounds. He is able to read programmed texts and is accompanied by three cubes, as can be seen in Figure 2, with which it is possible to compete with him. New games are released as the interaction grows, and it's necessary to have a mobile device running Android or iOS for the robots processing to run (MEET COZMO, 2017).

Figure 1 – JD and its main features.



Source: <https://www.robotcenter.co.uk/products/ez-robot-humanoid-revolution-jd>.

Figure 2 – Cozmo is a small robot focused on entertainment.



Source: <https://www.amazon.com/Anki-000-00048-Cozmo/dp/B01GA1298S>.

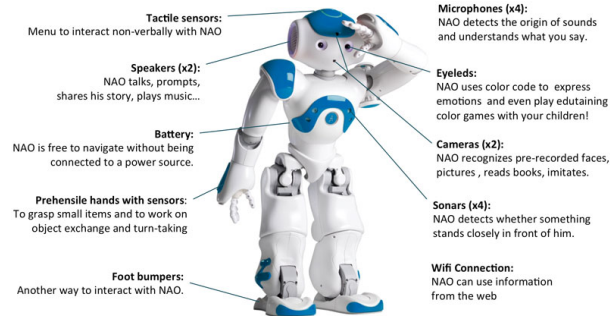
3.3.3 NAO

One of the most popular robots among researchers today is NAO, from the French company SoftBank Robotics, the world leader in humanoid robots. Defined by the creators as an interactive companion robot, it measures 58cm in height and is the first robot of the company, having been released in 2006 and currently in its fifth version (DISCOVER NAO, 2017). Despite having a very high cost, more than 10.000 NAOs have already been marketed around the world. It has several sensors, as can be seen in Figure 3, besides having its own operating system, called NAOqi. Among the various characteristics of this robot, we can highlight the facial and voice recognition, because it can autonomously recognize a face after being introduced to it, as well as remember the voice of anyone who it interacts with.

3.3.4 UXA-90

UXA-90 is a humanoid robot developed by South Korean company Robo Builder, which focuses on humanoid and educational robots. At about 1 meter in height, the UXA-90 is con-

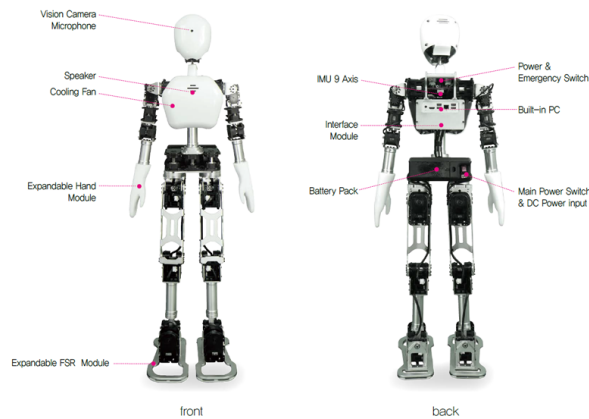
Figure 3 – NAO interactive companion robot and its features.



Source: http://zeitgeistlab.ca/doc/tactile_internet.html.

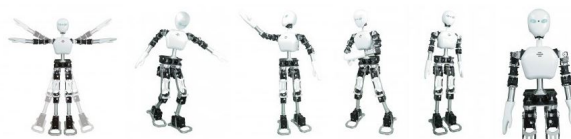
sidered a multipurpose robot, and one of the uses suggested by the manufacturer is the annual RoboCup Robotics competition. Its main feature is a drop sensor that allows it to stand up autonomously, besides being able to perform several movements, as shown in Figure 5. Another interesting feature is the possibility of using 3D printers to create parts that can replace various components of the robot (UXA-90, 2017). The main features of UXA-90 can be seen in Figure 4.

Figure 4 – UXA-90 and its components.



Source: <https://robosavvy.com/store/uxa90-light.html>.

Figure 5 – UXA-90 is able to mimic various human movements.



Source: <https://robosavvy.com/store/uxa90-light.html>.

3.3.5 iRobot Create

iRobot Create is a special version of the iRobot Roomba robot vacuum cleaner produced for researchers. Created by the US company iRobot, specialized in domestic robots, this version does not have the function of a vacuum cleaner, but maintains the original characteristics of the cleaning device. It allows sounds in the form of beeps and movements to be programmed, in addition to allow other sensors and cameras to be attached to it (IROBOT CREATE 2, 2017). iRobot Creator can be viewed in Figure 6.

Figure 6 – iRobot Create is a special version of the Roomba robot vacuum cleaner for researchers.

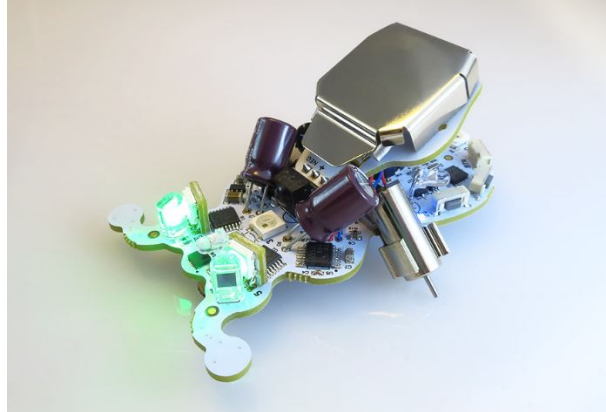


Source: <http://www.irobot.com/About-iRobot/STEM/Create-2.aspx>.

3.3.6 Ringo

Ringo is a small robot developed by the Canadian company PlumGeek. As we can see in Figure 7, it has a shape that resembles an insect, having an educational focus and allowing different behaviors such as sound and lights to be defined. It has several sensors, which can "chase" light, detect barriers and extremities, and is exceptionally fast in its movements. Another interesting feature of Ringo is its ability to communicate wirelessly with other Ringos, creating a "swarm" (RINGO2 - THE ROBOT, 2017).

Figure 7 – Ringo is a small insect-shaped robot.



Source: <http://www.plumgeek.com/ringo.html>.

3.3.7 Asimo

Asimo is one of the most advanced humanoid robots ever made. It was created by Honda back in 2000, having many abilities and sensors that allow for autonomous navigation and being able to recognize moving objects, postures, gestures, its surrounding environment, sounds and faces. It stands 130cm tall and weights 54kg (ASIMO, 2017). Asimo can be seen in Figure 8.

Figure 8 – Asimo executing one of the many tasks it is capable of.



Source: http://2.bp.blogspot.com/_MgfFnb8nlkU/TIEJS98HHiI/AAAAAAAAEJK/oFKmnREtVGo/s1600/asimo-honda.jpg.

3.3.8 PARO

PARO is a therapeutic robot designed after a Canadian baby harp seal intended to be used in hospitals and nursing homes as a way of calming patients and provoking emotional responses. It was created by Japanese Takanori Shibata and has many features, including 5 sensors: tactile, light, audition, temperature, and posture sensors. It can learn its name if the person keeps

repeating it, recognizes touch and reacts differently according to the part of the body it is being touched, and distinguishes lights intensities as well as flashes of light (PARO THERAPEUTIC ROBOT, 2017). PARO can be seen in Figure 9.

Figure 9 – PARO robot interacting with a patient with dementia.



Source: <https://www.thestar.com/content/dam/thestar/news/insight/2015/10/05/meet-paro-a-furry-friend-to-dementia-patients/paro-tab-1-or-2.jpg.size.custom.crop.1086x724.jpg>.

3.3.9 Robovie-II

Robovie-II is a very advanced robot that includes 10 tactile sensors, an omni-directional vision sensor, two microphones to listen to human voices, and 24 ultrasonic sensors for detecting obstacles, measuring 120 cm in height (KAHN et al., 2008). It was developed by researchers at the Advanced Telecommunications Research Institute in Japan and can be seen in Figure 10.

Figure 10 – Robovie-II during an experiment at a supermarket.

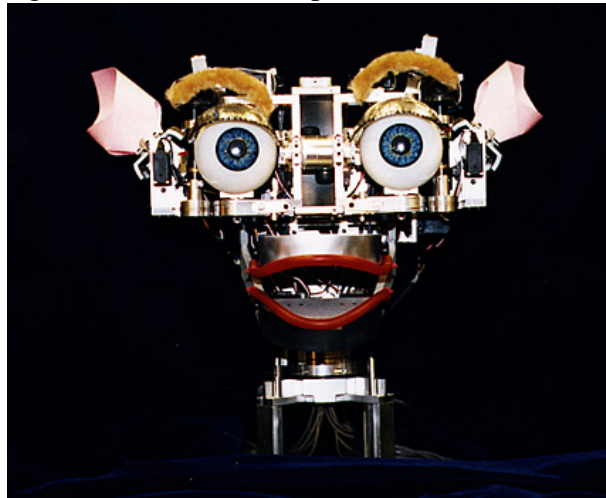


Source: <http://g1.globo.com/Noticias/Tecnologia/foto/0,,34577593-FMM,00.jpg>.

3.3.10 Kismet

Kismet is a robot head created by Dr. Cynthia Breazeal in the late 1990s at Massachusetts Institute of Technology as an experiment in affective computing, being able to recognize and simulate emotions. It was the first robot made with the intention of being social, speaking a "proto-language" (changing pitch, timing, articulation, etc) and displaying emotional expressions through his face. It was designed with human models of intelligent behavior in mind (KISMET, THE ROBOT, 2017). Kismet can be seen in Figure 11.

Figure 11 – Kismet, the pioneer in social robots.



Source: <http://www.cc.gatech.edu/athomaz/classes/CS8803-HRI-Spr08/Geo/images/Kismet2.jpg>.

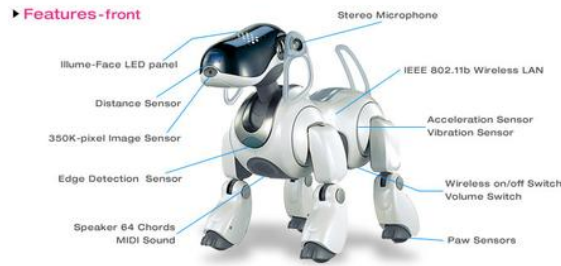
3.3.11 Aibo

Aibo is a pet-like robot created by Sony and launched in 1998. It is able to develop from a newborn puppy to an adult with a personality shaped by the interaction with their owners and surroundings, having multiple head and body sensors, clicking ear actuators, a chest-mounted proximity sensor, expressive face and Wi-Fi, as identified in Figure 12. It was the first of its kind. Aibo is no longer produced (since 2006) and its support ended in 2013 (AIBOS HISTORY, 2017).

3.3.12 Jibo

Jibo is a social robot created by Cynthia Breazeal and expected to launch in 2017. Jibo is seen as a revolution in the world of social robots, acting as a companion at home, taking pictures, playing music, reminding humans of activities and tasks, etc. It has had many problems with its development, as it uses the cloud to recognize and process information, such as image (i.e., with whom it is speaking to) and sound (i.e., voice recognition) (JIBO DELAYED, 2016). Jibo

Figure 12 – Aibo and its main features.



Source: https://cdn.shopify.com/s/files/1/0059/3932/files/aibo_1_large.jpg?198.

can be seen in Figure 13.

Figure 13 – Jibo and its creator, Cynthia Breazeal.



Source: <http://spectrum.ieee.org/image/MjUyNjg3Ng.jpeg>

3.3.13 Bandit

Bandit was designed by Maja Matarić's research lab at the University of Southern California and consists of servo-motors and rapid-prototyped parts. Its updated design and fabrication were performed by BlueSky Robotics. It was created to encourage and teach social behavior to children with autism, as well as help the elderly and stroke patients with their physical and cognitive exercises (BANDIT, 2017). Bandit can be seen in Figure 14.

Figure 14 – Bandit and its creator, Maja Matarić, during a TEDTalk.



Source: <https://gereports-prd.s3.amazonaws.com/wp-content/uploads/2014/12/Bandit-II-socially-assistive-robot-GEreports.jpg>

Table 3: Social robots and their general classification, based on the categories defined by Fong, Nourbakhsh and Dautenhahn (2003)

Robot	Social classification	Main design issues	Applications
JD	Socially interface, socially situated and socially embedded	<ul style="list-style-type: none"> • Design approach: <i>Biologically designed</i> • Embodiment: <i>Anthropomorphic</i> • Emotion: <i>Artificial emotions, body language and emotional speech</i> • Dialog: <i>Natural language</i> • Personality: <i>Artificial being</i> • Human-oriented perception: <i>people tracking, speech recognition, gesture recognition, and facial perception</i> 	Education

Continued on next page

Table 3 – continued from previous page

Robot	Social classification	Main design issues	Applications
Cozmo	Social receptive, socially situated and socially embedded	<ul style="list-style-type: none"> • Design approach: <i>Biologically designed</i> • Embodiment: <i>Zoomorphic</i> • Emotion: <i>Artificial emotions, emotional speech, facial expression, and body language</i> • Dialog: <i>Low-level</i> • Personality: <i>pet or creature and cartoon</i> • Human-oriented perception: <i>people tracking, speech recognition and facial perception</i> 	Entertainment

Continued on next page

Table 3 – continued from previous page

Robot	Social classification	Main design issues	Applications
NAO	Social receptive, socially situated, sociable, socially embedded and socially intelligent	<ul style="list-style-type: none"> ● Design approach: <i>Biologically designed</i> ● Embodiment: <i>Anthropomorphic</i> ● Emotion: <i>Artificial emotions, body language</i> and emotional speech ● Dialog: <i>Natural language</i> ● Personality: <i>Artificial being</i> ● Human-oriented perception: <i>people tracking, speech recognition, gesture recognition, and facial perception</i> 	Education and entertainment

Continued on next page

Table 3 – continued from previous page

Robot	Social classification	Main design issues	Applications
UXA-90	Social receptive, socially situated and socially embedded	<ul style="list-style-type: none"> ● Design approach: <i>Biologically designed</i> ● Embodiment: <i>Anthropomorphic</i> ● Emotion: <i>Artificial emotions, body language</i> and emotional speech ● Dialog: <i>Natural language</i> ● Personality: <i>Human-like</i> ● Human-oriented perception: <i>people tracking, speech recognition, gesture recognition, and facial perception</i> 	Education and entertainment
iRobot Create	Socially evocative	<ul style="list-style-type: none"> ● Design approach: <i>Functionally designed</i> ● Embodiment: <i>Functional</i> ● Emotion: <i>Artificial emotions</i> ● Dialog: <i>Non-verbal</i> ● Personality: <i>Tool-like</i> ● Human-oriented perception: none 	Service

Continued on next page

Table 3 – continued from previous page

Robot	Social classification	Main design issues	Applications
Ringo	Socially evocative and socially situated	<ul style="list-style-type: none"> • Design approach: <i>Functionally designed</i> • Embodiment: <i>Functional</i> • Emotion: <i>Artificial emotions</i> • Dialog: <i>Low-level</i> • Personality: <i>Tool-like</i> • Human-oriented perception: none 	Education and entertainment
Asimo	Socially receptive, socially situated, sociable, socially embedded and socially intelligent	<ul style="list-style-type: none"> • Design approach: <i>Biologically designed</i> • Embodiment: <i>Anthropomorphic</i> • Emotion: <i>Artificial emotions, body language</i> and emotional speech • Dialog: <i>Natural language</i> • Personality: <i>Artificial being</i> • Human-oriented perception: <i>people tracking, speech recognition, gesture recognition, and facial perception</i> 	Research and entertainment

Continued on next page

Table 3 – continued from previous page

Robot	Social classification	Main design issues	Applications
PARO	Sociable, socially situated, and socially embedded	<ul style="list-style-type: none"> • Design approach: <i>Biologically designed</i> • Embodiment: <i>Zoomorphic</i> • Emotion: <i>Artificial emotions and emotional speech</i> • Dialog: <i>low-level</i> • Personality: <i>Pet or creature</i> • Human-oriented perception: <i>people tracking and speech recognition</i> 	Therapy and re-search
Robovie II	Social receptive, socially situated, sociable, socially embedded and socially intelligent	<ul style="list-style-type: none"> • Design approach: <i>Biologically designed</i> • Embodiment: <i>Caricatured</i> • Emotion: <i>Artificial emotions, emotional speech, facial expression, and body language</i> • Dialog: <i>Natural language</i> • Personality: <i>Artificial being</i> • Human-oriented perception: <i>people tracking, speech recognition, gesture recognition, and facial perception</i> 	Research

Continued on next page

Table 3 – continued from previous page

Robot	Social classification	Main design issues	Applications
Kismet	Sociable and socially embedded	<ul style="list-style-type: none"> ● Design approach: <i>Biologically designed</i> ● Embodiment: <i>Caricatured</i> ● Emotion: <i>Artificial emotions, emotional speech, and facial expression</i> ● Dialog: <i>Natural language</i> ● Personality: <i>cartoon and pet or creature</i> ● Human-oriented perception: <i>people tracking, speech recognition, and facial perception</i> 	Research
Aibo	Sociable, socially situated, and socially embedded	<ul style="list-style-type: none"> ● Design approach: <i>Biologically designed</i> ● Embodiment: <i>Zoomorphic</i> ● Emotion: <i>Artificial emotions and emotional speech</i> ● Dialog: <i>low-level</i> ● Personality: <i>Pet or creature</i> ● Human-oriented perception: <i>people tracking and speech recognition</i> 	Entertainment

Continued on next page

Table 3 – continued from previous page

Robot	Social classification	Main design issues	Applications
Jibo	Social evocative, Social interface, Socially receptive, sociable, socially situated, socially embedded and socially intelligent	<ul style="list-style-type: none"> • Design approach: <i>Biologically designed</i> • Embodiment: <i>Caricatured</i> • Emotion: <i>Artificial emotions and emotional speech</i> and facial expression • Dialog: <i>Natural language</i> • Personality: <i>Artificial being</i> • Human-oriented perception: <i>people tracking, speech recognition, gesture recognition, and facial perception</i> 	Service and entertainment
Bandit	Socially receptive, sociable, socially embedded	<ul style="list-style-type: none"> • Design approach: <i>Biologically designed</i> • Embodiment: <i>Anthropomorphic</i> • Emotion: <i>Artificial emotions and emotional speech</i> • Dialog: <i>Natural language</i> • Personality: <i>Artificial being</i> • Human-oriented perception: <i>people tracking and gesture recognition</i> 	Therapy, education and research

Although not all of these robots can be thought of as social (if we consider the way they come from the manufacturer), they are all programmable and can have their behavior altered so that they act socially. The *iRobot Roomba Create*, for example, is functionally designed and would hardly be seen as a social device, but studies have identified, as the next Chapter shows, that it acts as a social partner at home as people treat it in a similar way as they treat pets (SUNG et al., 2007).

Socially assistive robots, however, are more challenging and it wouldn't be easy to adapt all of these examples to act as such. *Bandit*, nonetheless, is an example of robot designed specifically for SAR studies. Similarly, *PARO* is also used in the area.

4 HUMAN PERCEPTION OF SOCIAL ROBOTS

According to Fong, Nourbakhsh and Dautenhahn (2003, pg, 40), "a key difference between conventional and socially interactive robots is that the way in which a human perceives a robot establishes expectations that guide his interaction with it." This perception, particularly of the robot's autonomy, intelligence, and capacities is influenced by many factors. Clearly, the human's preconceptions, knowledge, and prior exposure to the robot, or similar robots, have a strong influence, as well as the robot's design issues (embodiment, dialog, etc.). In addition, the human's experience over time will without any doubt change one's judgment, i.e., initial impressions will change as one gets more comfortable and intimate with the robot.

4.1 ATTITUDES TOWARDS ROBOTS

Some studies have examined how people, more specifically children, perceive robots and what kinds of behaviors they may show when interacting with robots (FONG; NOURBAKHSH; DAUTENHAHN, 2003). These studies were conducted mostly through informal yet guided interviews and drawings the children made of the robots, alongside with a story about them. It was found that children are inclined to believe that robots are geometrical forms with human characteristics (i.e, anthropomorphism). Furthermore, the children tend to attribute free will to the robots in their stories and to include them in familiar, social contexts. Lastly, most of the children gave preferences, emotion, and male gender to the robots.

Other studies described by Fong, Nourbakhsh and Dautenhahn (2003) investigated the attitude of people towards intelligent service robots in domestic environments, and some significant findings include that people's views of intelligent robots are greatly influenced by science fiction, with the preferred robot being machine-like in its appearance, with serious personality and verbal communication, including voice recognition and synthesized speech, using human-like voice.

Although Roomba, a domestic robotic autonomous vacuum, does not possess social cues, it is well known for creating emotional bonds. As Sung et al. (2007) showed on a study with participants of a forum aimed at owners of Roombas, besides monitoring and rescuing their vacuums in case of problems, the participants watch the work of their Roomba (some people have more than five of these vacuum cleaners) and this makes them feel happier. Additionally, participants frequently use associations of everyday life to engage with the robot, often assigning personality, name, and gender to them. Finally, it was found that these participants give enough value to the vacuum cleaner to change the layout of their home so that the robot can work better and to recommend and lend them to other people so they can try it out; at the same time, they show great concern about how these people will take care of the robot. In addition to the findings of this study, there are reports of people whose Roombas broke and were sent to technical assistance with letters (GOLDHILL, 2014). One of them said, "please fix my Roomba

because my Roomba's my friend. I don't want another Roomba, I want you to fix this one."

4.1.1 Effects of emotion

Many studies have shown that having an expressive face and indicating attention with movement can help make a robot more persuasive to interact with, as researchers try to answer questions like "would people find interaction with a robot that had a human face more appealing than a robot with no face?". Additionally, some studies show that, even with a very simple embodiment, the "core" emotions of anger, happiness, and sadness are easily recognized (FONG; NOURBAKHS; DAUTENHAHN, 2003). Cozmo, one of the top selling robot toys (see 3.3.2), gets "angry" if the human doesn't play with it, displaying these emotions through his eyes and making sounds, as well as moving his "arms-like" structure up and down as a signal of discontentment.

4.1.2 Effects of appearance and dialog

Dialog can bring problems to the perception the human has of the robot, as some characteristics and qualities can be attributed to the robot based on associations of stereotyped behavior created based on the dialog, misleading the understanding of how the robots works. Some studies have tried to understand the affect a robot's appearance and dialog have on how people act towards the robot, as well as their thoughts about it, through measures that include scales for rating anthropomorphic and mechanistic attributes, measures of model richness or certainty, and compliance with a robot's requests (FONG; NOURBAKHS; DAUTENHAHN, 2003). One important study finding was that neither ratings, nor behavioral observations alone are enough to completely describe human responses to robots. Additionally, it was found that dialog influences development and change of mental models more than differences in appearance.

4.1.3 Effects of personality

Studies have shown that a charming personality will not necessarily create the best cooperation with a robotic assistant. Many effects occur when a robot exhibits personality, even if that wasn't intended by the designer. A number of commercial products have been focusing on personality as a way to engage humans on an effective interaction. In either a positive or negative way, personality can also impact task performance (FONG; NOURBAKHS; DAUTENHAHN, 2003). Cozmo is said to have "a one-of-a-kind personality that evolves the more you hang out" (MEET COZMO, 2017), and is intended not to obey at first, with the creators using the slogan *well behaved robots rarely make history*.

The same approach of Cozmo was exploited by Sony's Aibo, as it used personality to attract and cultivate effective interaction. Aibo is well known to have created bonds through his

personality with their owners. One very interesting news report showed a video of the funeral of some Aibo robots in Japan. As Sony stopped production and Aibo's last repair center closed in 2014, their owner had no choice but to stop using them once they couldn't be fixed anymore. In the funeral, an interesting statement by the person conducting the ceremony was that "the animate and inanimate are not separated in this world" (CANEPARI; COOPER, 2015).

4.1.4 Field studies on social robots

Some of the first studies investigating people's willingness to closely interact with social robots show that children were found to be more engaged than adults, with responses that varied with gender and age, as well as friendly personality as a factor to prompt better interaction than an angry personality (SCHEEFF et al., 2002).

Dautenhahn and Billard (1999) conducted a study with a quantitative method for evaluating robot-human interaction, in a similar way to that of evaluation of animal behavior used by ethologists through observation. Interaction style differences of children playing with a socially interactive robot toy and a non-robotic toy have been studied with this method.

In order to validate the design patterns proposed in Section 2.4, Kahn Jr et al. (2012) made an experiment with 90 children (9-, 12-, and 15-year-olds) that initially interacted with a humanoid robot, Robovie (see 3.3.9), in 15-min sessions that ended when an experimenter interrupted Robovie's turn at a game and put Robovie into a closet against its explicit objections. After that, each child was then engaged in a 50-min structural–developmental interview.

The researchers then concluded that all the children engaged in physical and verbal social behaviors during the interaction sessions, and based on the interview data, the majority of them believed Robovie was intelligent, had feelings and was a social being. Regarding the robot's moral standing, children believed Robovie deserved fair treatment and should not be harmed psychologically, but they did acknowledge Robovie's lack of liberty and civil rights, understanding that the robot could be bought or sold and that it couldn't vote or be paid by work performed. More than half of the 15-year-olds in the study did conceptualize Robovie with characteristics mentioned previously (e. g., having feelings), but in a lesser degree than the others (9- and 12-year-olds).

4.1.5 Human response to SAR

All the studies presented include robots that are somehow social, but not all of them act in a caring, assistive way. SAR researchers take advantage of the results of these studies with regular social robots in order to build robots focused specific on being assistive or related to caring in some way.

Many studies have tested PARO (see 3.3.8), the robotic seal, as a helping character, specially within the elderly. A recent study with people with dementia indicated that PARO is a social

robot that is viable for use with people with mid to late-stage dementia and might have a role in improving their mood and social interaction (MOYLE et al., 2013). One *vignette* included in the study talked about an experiment conducted with a man, named Thomas, with moderate to late stage dementia and living in a nursing home. Thomas wasn't included in the main study as researchers wanted to see his particular reaction, as he always follows the same routine, sitting in his chair and waiting patiently to be taken back to his room by the care staff, not interacting with others in the facility and not talking to anyone, even his daughter. The staff believes he is content with his routine, as he doesn't complain about anything. His daughter, however, believes that Thomas isn't stimulated enough by the staff, as they might not have sufficient time to do so, resulting in his current state of apathy.

Thomas was presented with PARO and showed surprise right away, with his facial expression indicating he wasn't sure what the robot was. Then, he gently patted PARO as the robot responded looking at him. After that, Thomas placed PARO into his shoulder in the same way people do with babies, and looked happy while he was cuddling PARO. He smiled as PARO responded to his touches, and kept stroking the robot and reacting to PARO's feedback. Thomas spent the day with the robot, and once the researchers went to take PARO from Thomas, his face showed discontent and he kept holding PARO's flippers as a way to retain the robot.

Then, the research team asked the research facilitator to gently go to take PARO from Thomas and to tell him to say goodbye to the robot. Thomas released PARO and looked directly at PARO's face saying in a loud voice "goodbye PARO". The eyes of the staff that was watching got misty and became filled with tears, as this was the first time they have heard Thomas speak in 2 (two) years. They thought Thomas could not speak and had stopped communicating with him, and this reminded them of the importance of keeping communication with people with dementia even when it seems they have lost the ability to communicate.

Based on all the studies mentioned, it is clear that humans do engage and create bonds with technological devices, especially embodied ones such as robots. Thus, it is a good idea to explore that engagement in order to provide care and help to humans in need (MATARIĆ, 2013).

4.2 EVALUATING HRI

4.2.1 Metrics of evaluation

For the study of socially interactive robots to be valid, it is necessary to understand the interaction patterns between humans and robots. As a very recent area, HRI still needs more studies regarding patterns and criteria for interaction evaluation. Some researchers created metrics with this goal in mind. In a recent research, Murphy and Schreckenghost (2013) classified 42 metrics, although there's still no consensus on all the proposed metrics.

The work of Steinfeld et al. (2006) proposes common metrics to evaluate HRI, and is the

most used work in the area, although Murphy and Schreckenghost (2013) says that Steinfeld et al. (2006)'s approach is oriented toward an engineering orientation and does not completely address the social interaction context, and so both the engineering and social interaction perspectives require further investigation to develop metrics and methods of evaluation. However, for this work, we will use some of the metrics defined by Steinfeld et al. (2006), as a work very great relevance (see A).

Within the metrics of Steinfeld et al. (2006), we find five main **social metrics**:

- *Interaction characteristics*: regarding to the interaction style or social context (e.g., the environment where it happens and if different people interact differently with the same robot).
- *Persuasiveness*: when the robot serves as a way to change the behavior, feelings or attitudes of humans.
- *Trust*: important factor to measure as it can influence expectation on systems that are complex and work in dynamic environments.
- *Engagement*: an important metric is to measure the effectiveness of different social characteristics, like emotion, dialog, and personality, and for capturing attention and holding interest, as social interaction is well known to effectively engage users.
- *Compliance*: social aspects (e.g., appearance) can influence how much cooperation a human gives to a robot. Therefore, measuring compliance can give good perspective into the effectiveness of the robot design;

It is also important to evaluate whether or not the subject is used to technology and how good they are in using technological devices, as that might interfere on the results. In addition, Torta et al. (2014) add the following metrics in their work:

- *Anxiety*: this concept measures whether or not the system causes anxious or negative emotional reactions during its use, influencing the usefulness and easiness of the system.
- *Perceived adaptability*: the conditions and the capacities (e.g., mobility) of users change over time. Assistive technology should give users the sense that it can be adaptive towards their needs, making them accept the system more and find it more useful.
- *Perceived ease of use*: how easy the users thinks the system is.
- *Perceived sociability*: how the performance of the system is, regarding sociable behavior.
- *Social presence*: it can be characterized as the feeling of being in the company of a social individual, having direct affect on the perceived satisfaction in using the system and thus influencing the intention to use it.

Torta et al. (2014) metrics are evaluate based on questionnaires, as seen in Figure 15, and measured through a 5-point Likert scale.

Torta et al. (2014) address metrics more specific to SAR. Feil-Seifer, Skinner and Matarić (2007) add more specific SAR benchmarks, like *social success*, *impact on the user's care*, *impact on caregivers*, and *impact on the user's life*, and more general ones, like *autonomy*, *imitation* and *privacy*.

From the *social success* benchmark, an important aspect to evaluate is whether the social identity of the robot affects the user's task performance, including both the personality and the role of the robot (FEIL-SEIFER; SKINNER; MATARIĆ, 2007).

4.2.2 Human studies methods

4.2.2.1 Types of study design

According to Bethel and Murphy (2010), there are three types of study design:

- **Within-subject:** every participant goes through all of the experimental settings being measured;
- **Between-subject:** participants go through only one of the experimental circumstances, and the number of experimental groups depends on the number of experimental settings being considered;
- **Mixed-model:** uses both between-subjects and within-subjects designs.

For example, if we want to test whether some function of a robot has the same effect as a computer on the participant, we would ask all the participants to do the same task with both the computer and the robot using the within-subject design, but could create two groups (the ones that are going to interact with the computer and the ones interacting with the robot) using the between-subject design. We could also use the mixed model design and create three groups, one that interacts only with the computer, another that interacts only with the robots, and a third one that does both.

4.2.2.2 Methods of evaluation

Until recently, according to Murphy and Schreckenghost (2013), the focus in HRI was the development of specific robotic systems and applications while neglecting methods of evaluation and metrics. Some methods of evaluation have been adopted and/or modified from such fields as human-computer interaction, psychology, and social sciences (KIDD; BREAZEAL, 2005);

According to Kidd and Breazeal (2005), there are five primary methods of evaluation used for human studies in HRI:

- **Self-assessments:** paper or computer-based psychometric scales, questionnaires, or surveys are commonly used;
- **Interviews:** open-ended or close-ended questions can be asked by the researcher in the interview;
- **Behavioral measures:** recorded video sessions are often used to analyze the participants' behavior;
- **Psychophysiology measures:** multiple physiological signals should be used, like heart rate variability and respiration rates;
- **Task performance metrics:** can be used to measure how well a person or team performs or completes a task or tasks;

Murphy and Schreckenghost (2013) have two main recommendations for HRI studies with humans: the use *larger sample sizes* to appropriately represent the population being studied, and the use of *at least three methods of evaluation* to converge validity.

The most common way to evaluate HRI is through interviews and self-assessments, with questions and the Likert scale, such as the evaluation of Torta et al. (2014) metrics described in 4.2.1.

Bartneck, Croft and Kulic (2009) created a series of questionnaires intended to measure the users' perception of robots, called "Godspeed", named like that as "it is intended to help creators of robots on their development journey" (BARTNECK; CROFT; KULIC, 2009, pg. 78). The questionnaires can be seen in Figure 16.

Figure 15 – Torta et al. (2014) questionnaires.

ID	Construct	Description
ANX	Anxiety	This construct measures whether or not the system evokes anxious or negative emotional reactions during usage and influences perceived usefulness and perceived ease of use (see Fig. 6). Questions are: If I should use the robot, I would be afraid to make mistakes with it. If I should use the robot, I would be afraid to break something. I find the robot scary. I find the robot intimidating.
PAD	Perceived adaptability	The conditions and the abilities (e.g., mobility, sensory abilities, effects of medication) of users change over time. Assistive technology, and in particular robots that support the ecology of ageing, need to adapt to these changes [16]. If people perceive the system to be adaptive towards their needs, they will find it more useful and will accept the system more easily in their own living circumstances. Questions are: I think the robot can be adaptive to what I need. I think the robot will only do what I need at that particular moment. I think the robot will help me when I consider it to be necessary.
PEOU	Perceived ease of use	The degree to which one believes that using the system would be free of effort. Questions are: I think I will know quickly how to use the robot. I find the robot easy to use. I think I can use the robot without any help. I think I can use the robot when there is someone around to help me. I think I can use the robot when I have a good manual.
PS	Perceived sociability	The perceived ability of the system to perform sociable behavior. Related studies have found that the construct is a determining influence on social presence and perceived enjoyment, which further influences future intentions to use the system (see Fig. 6). Hence, a socially-assistive robot that supports vulnerable target groups needs social abilities to function as an assistive device. Questions are: I consider the robot a pleasant conversational partner. I find the robot pleasant to interact with. I feel the robot understands me. I think the robot is nice.
SP	Social presence	Social presence can be described as the feeling of being in the company of a social entity: the perceptual illusion of non-mediation [22, 26]. If the technology is shaped like an animal or even humanoid this effect gets even stronger. The social presence of a system has a direct influence on the perceived enjoyment in using the system, which further has an influence on the intention to use the system (see Fig. 6). Questions are: When interacting with the robot I felt like I'm talking to a real person. It sometimes felt as if the robot was really looking at me. I can imagine the robot to be a living creature. I often think the robot is not a real person. Sometimes the robot seems to have real feelings.

Source: (TORTA et al., 2014)

Figure 16 – The Godspeed questionnaires.

GODSPEED I: ANTHROPOMORPHISM

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Fake 偽物のような	1	2	3	4	5	Natural 自然な
Machinelike 機械的	1	2	3	4	5	Humanlike 人間的
Unconscious 意識を持たない	1	2	3	4	5	Conscious 意識を持っている
Artificial 人工的	1	2	3	4	5	Lifelike 生物的
Moving rigidly ぎこちない動き	1	2	3	4	5	Moving elegantly 洗練された動き

GODSPEED II: ANIMACY

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Dead 死んでいる	1	2	3	4	5	Alive 生きている
Stagnant 活気のない	1	2	3	4	5	Lively 生き生きとした
Mechanical 機械的な	1	2	3	4	5	Organic 有機的な
Artificial 人工的な	1	2	3	4	5	Lifelike 生物的な
Inert 不活発な	1	2	3	4	5	Interactive 対話的な
Apathetic 無関心な	1	2	3	4	5	Responsive 反応のある

GODSPEED III: LIKEABILITY

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Dislike 嫌い	1	2	3	4	5	Like 好き
Unfriendly 親しみにくい	1	2	3	4	5	Friendly 親しみやすい
Unkind 不親切な	1	2	3	4	5	Kind 親切な
Unpleasant 不愉快な	1	2	3	4	5	Pleasant 愉快な
Awful ひどい	1	2	3	4	5	Nice 良い

GODSPEED IV: PERCEIVED INTELLIGENCE

Please rate your impression of the robot on these scales:

以下のスケールに基づいてこのロボットの印象を評価してください。

Incompetent 無能な	1	2	3	4	5	Competent 有能な
Ignorant 無知な	1	2	3	4	5	Knowledgeable 物知りな
Irresponsible 無責任な	1	2	3	4	5	Responsible 責任のある
Unintelligent 知的でない	1	2	3	4	5	Intelligent 知的な
Foolish 愚かな	1	2	3	4	5	Sensible 賢明な

GODSPEED V: PERCEIVED SAFETY

Please rate your emotional state on these scales:

以下のスケールに基づいてあなたの心の状態を評価してください。

Anxious 不安な	1	2	3	4	5	Relaxed 落ち着いた
Agitated 動揺している	1	2	3	4	5	Calm 冷静な
Quiescent 平穏な	1	2	3	4	5	Surprised 驚いた

Source: (BARTNECK; CROFT; KULIC, 2009)

5 EXPERIMENT

In order to validate the aspects of HRI, an experiment is proposed, along with information about the chosen robot that is going to be used.

The experiment is based on studies created for the SAR area, and is focused on visually impaired people.

5.1 COMPARISON OF ROBOTS AVAILABLE FOR RESEARCH

In order to carry out an experiment in which to use the evaluation criteria studied, it was necessary to choose a robot. Currently, the market offers several options of robots, from those that focus only on entertainment to those that allow programming their behavior. The characteristics of each robot vary according to the manufacturer, the price and the purpose of the robot. Therefore, a comparison was necessary between some robots available.

After an analysis of the most popular robots on the Internet and those that are most used in researches, six options were chosen from those introduced in 3.3. The comparison is detailed in Table 4.

5.1.1 Chosen robot

The robot selected for this research was JD, from E-Z Robots (see 3.3.1), as it has some characteristics (such as facial and voice recognition) that can be used to test a large range of HRI aspects, besides being an excellent value for money compared to other available robots.

5.2 MOTIVATION

The idea of this experiment comes from the fact that visually impaired people still have a lot of needs to be addressed and that technology has much to offer. The author has worked with *Giovani França Pereira*, blind UCS student, on Data Structures studies using Lego's. This experience helped on developing the first drafts of this experiment, as color identification was thought to be helpful not only with the Lego's (as *Giovani* could only identify them by touch), but other daily tasks as well.

Matarić (2013) states that the SAR technology, that brings together social and assistive robots, is here to help people on tasks for which we don't have enough caregivers. So instead of replacing people, we are filling gaps. For instance, visually impaired people don't have others assisting them all the time, and through technology they have been gaining a lot more independence.

One could think that we don't need robots to do certain tasks, as a laptop or smartphone could do the job, specially visually impaired people, who already use laptops with great skills.

Table 4 – Comparison of robots.

Robot	Program- ming type	Facial Recog- nition	Speech Recog- nition	Sounds	Other features	Ship to Brazil	Price
NAO	Python, C++, Java or JavaScript	Yes	Yes	Voice and other sounds	Environment recognition and other sensors	Yes	R\$99.090
UXA- 90	C#	Sim	Yes	Voice and other sounds	Humanoid	Yes	\$22.000
e-z JD	C# e C++	Yes	Yes	Voice and other sounds	Humanoid	Yes	\$430
iRobot Cre- ator	Python scripts (Arduino based)	No	No	Only bips	Cliff and wall detection; Allows other sensons and cameras to be attached	No	\$200
Ringo	Arduino	No	No	Only bips	Cliff detection; Line following; Light sensors; Allow wireless communications with other Ringos	Yes	\$100
Cozmo	Scripts em Python	Yes	No (only through the app)	Voice and some sensors	Cliff detection	Yes	\$180

Source: Created by the author.

This work, however, has shown many examples of the beneficial use of robots as assistants. The studies presented show that robots can make people's lives easier, promote happiness, and avoid depression and anxiety. Researchers are still investigating the many aspects of robots in order to define what characteristics make them so much more beneficial than other technologies in certain tasks. Matarić (2013), however, has a very simple answer: it is our tendency to attribute human characteristics to machines. On doing so, we create bonds and have feelings for them, and that alone can make us more engaged on interacting with technological devices such as robots, and thus benefiting from them.

Visually impaired people are not included in the list of applications of the SAR area. However, from the definition of SAR (see 3.2) we can clearly add this kind of help for the blind. To support this idea, Maja Mataric, one of the pioneers in SAR and the author who coined the expression "socially assistive robotics," was asked through email about the topic, and her answer strongly encourages us to keep that experiment classified as a SAR topic. Her answer can be seen in Appendix B.

As SAR works with the most different kinds of special needs, like autism or post-stroke rehabilitation patients, this experiment was created keeping in mind that we shouldn't consider that someone won't benefit from the robot the same way a sighted person would just because they can't see it. Visually impaired people's lives might also be improved by a robot that is not only assistive, but also social. While the robot helps them with a task, it may also improve their self-confidence (e.g., on doing tasks without having to ask other people), making them feel happier and evoking other positive feelings, as well as motivating them to socialize more (e.g., talking about the robot with peers).

5.3 PROCEDURE

The experiment was executed with both JD and a laptop.

In the experiment, JD and the laptop helped a visually impaired person to prepare coffee or chocolate milk through vocal instructions. JD and the laptop were able to identify three different pods (aka capsules) for a *Nestle Dolce Gusto* machine: *espresso*, *coffee with milk*, or *chocolate milk*. In addition, they were able to give advice on how to operate the coffee machine. As braille is available only in their original boxes, these pods, when out of the box, are only identifiable by a sighted person. In this experiment, thus, blind people get help from both the laptop and JD on identifying those pods as if these people were "in the wild" (e.g., at work, school, etc).

Two sessions were conducted with each participant, in two different and non-consecutive days. In the first day, the participants learned how to operate the coffee machine and only JD helped half of the participants to prepare coffee, while the other half were helped only by the laptop. In the second day, those who interacted with JD in the first day then got help from the laptop and the others interacted with JD.

The objective was to investigate whether the participants would prefer the robot, as it is bio-

logically (anthropomorphically) embodied, or the laptop, which is only functionally embodied.

5.3.1 Evaluated metrics and results

From the metrics addressed in 4.2.1, the following were chosen and evaluated in the experiment:

- Interaction characteristics
- Subject's trust in the robot
- Subject's anxiety
- Perceived robot's anthropomorphism
- Perceived robot's social presence

These metrics were evaluated using a set of questionnaires in an interview, based on the work of Bartneck, Croft and Kulic (2009). The elaborated questionnaires can be seen in Appendix D.

A full description of the experiment, its procedure, evaluation and results can be seen in Appendix E.

5.4 FRAMEWORK

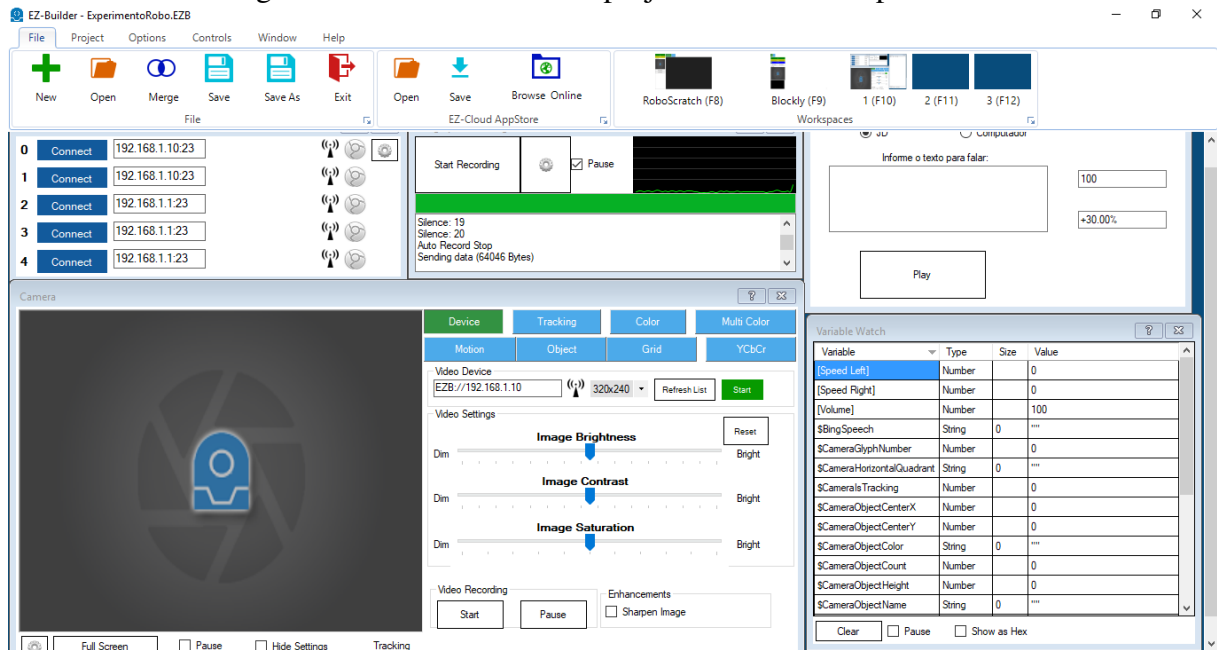
5.4.1 E-Z Builder

The software behind JD is called E-Z Builder. It runs on Windows and works with the idea of *plugins*, modules that work together inside a project. Each plugin is a library written in C#, and can be accessed through E-Z Builder. The plugins used in the experiment are shown in Figure 17.

The main plugins needed for the experiment came natively with E-Z Builder. The **Camera plugin** was used to identify the pods and the **Microsoft Bing Speech Recognition plugin** was used to recognize the participants' voice. Additionally, other more generic plugins were also used, like the **Variable Watch plugin** and the plugin that connects the software to JD itself.

JD itself does not run any major processing, except for a web server. Thus, JD accepts the *Server* mode, which allows one to use the computer running E-Z Builder to connect wirelessly to JD, or a *Client* mode, where JD itself connects to another device. For the experiment, JD was in the Server mode, a computer kept connected to it through the wifi and to the internet via a cable connection, allowing E-Z Builder to have access to both JD and the internet. The internet access is needed because the Microsoft API was used for voice recognition and text-to-speech, as the following section describes.

Figure 17 – The E-Z Builder project used in the experiment.



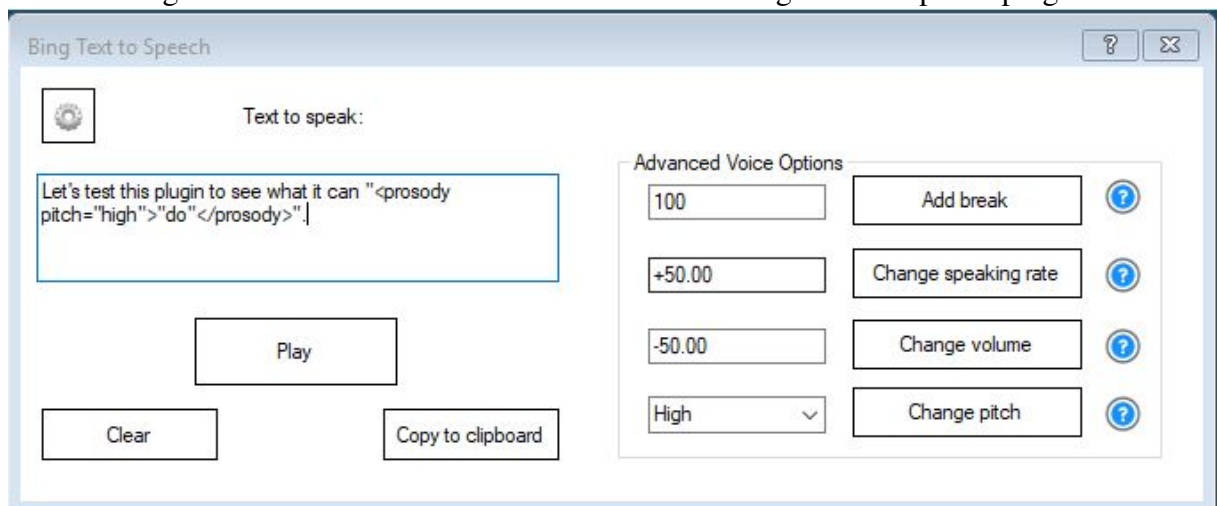
Source: Elaborated by the author.

5.4.2 Microsoft Bing Text-to-Speech plugin

For JD to speak Portuguese a new plugin was needed, as the E-Z Builder plugin for text-to-speech was English-only. Some free commercial voices were analyzed and the Microsoft Bing Speech API was chosen. Thus, a plugin was developed so that text could be sent to the Microsoft API platform and return as voice in Portuguese. The project was then published at the E-Z Robot website so that the community could use the plugin to make their robots speak any of the languages available.

An image of the final published version of the plugin can be seen in Figure 18.

Figure 18 – The final version of the Microsoft Bing Text-to-Speech plugin.



Source: Elaborated by the author.

5.4.3 Scripts

E-Z Builder has its own programming syntax as well as Scratch programming. E-Z Builder allows one to run scripts including variables and commands from all other added plugins. In the experiment, an option inside the Microsoft Bing Speech Recognition plugin was used to run the script, as seen in Figure 19 and Figure 20. Once this plugin was started, the script kept running until the last condition on the *if...else* chain was hit.

Figure 19 – The Bing Speech Recognition plugin settings with the button to edit the script.

The image shows a configuration window for the Bing Speech Recognition plugin. The window is titled "Config" and has a close button in the top right corner. It is divided into several sections:

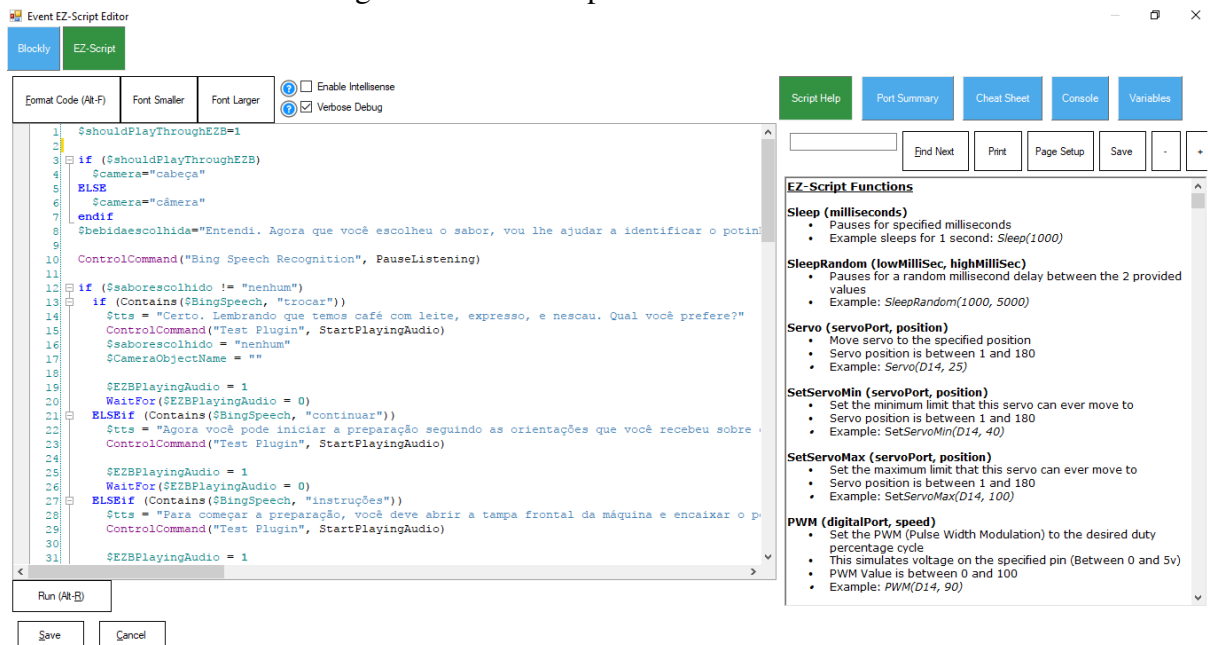
- Script:** A text area containing "Multiline Script" with a question mark icon on the left and an edit icon on the right.
- Variables:** A text area containing "\$BingSpeech" with a question mark icon on the left.
- API Key:** An empty text area with a question mark icon on the left and a "View Subscriptions" button on the right.
- Language:** A dropdown menu showing "pt-BR" with a question mark icon on the left and a dropdown arrow on the right.
- Record Settings:** A section with a checked checkbox for "Auto record using threshold" and three input fields: "Level Threshold" (0.05), "Silence Count" (20), and "Max Recording" (10). The "Level Threshold" field has a note "(Approx. 0.01 - 0.05)" and the "Max Recording" field has a note "(in seconds)".

At the bottom of the window are "Save" and "Cancel" buttons.

Source: Elaborated by the author.

The script with all the commands used and all the words JD recognized and responded to during the experiment can be seen in Appendix C.

Figure 20 – The script editor of E-Z Builder.



Source: Elaborated by the author.

6 CONCLUSION

6.1 WORK SYNTHESIS

HRI is a growing area of research where many challenges are faced, including what characteristics a robot should have so that it can work with the presence of people, usually in real world conditions. Yet many application areas are present in HRI, the assistive and educational robots is a promising one, addressing challenges on how robots can be used to transform human lives, particularly of people with special needs.

In order to engage humans in the interaction, there's another growing field of research that works together with HRI called the *socially interactive robots*. For this kind of robots, the social interaction between humans and robots is very important, involving social, emotive, and cognitive aspects of the interaction, where humans and robots interact as peers or companions. Many application areas are the focus of social robots, such as service, entertainment, therapy and education.

From the social robots' *service* application areas come the area of *SAR*, which is defined as the intersection of them, addressing all the problems that socially interactive robots face plus those of assistive robots, and focusing on helping people through social interaction instead of physical contact.

Many design issues are addressed toward HRI, some generic (e.g., robot's embodiment), others focused on social interaction (e.g., robot's dialog), and others being more important (or specific) to SAR (e.g., robot's personality, adaptability).

Various studies were presented, showing that it is well known that humans create bonds with robots and can engage more if the interaction is well designed. Thus, in order to validate some of the design issues addressed, an experiment regarding SAR was executed as a way to test some of the discussed design issues.

The results of the experiment are explained in an article that was submitted to the 13th Annual ACM/IEEE International Conference on Human Robot Interaction. The full article can be seen in Appendix E.

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APPENDIX A – SURVEY OF RELEVANT ARTICLES

The following attached PDF shows a survey that was made through *Google Scholar*, along with the *Portal de Periódicos da CAPES*. The relevance calculus was made using the following formula (2018 was used to avoid *division by zero*).

relevance = $\text{numberOfCitations} / (2018 - \text{yearOfPublication})$.

Source: Elaborated by the author.

Article	Author(s)	Year	Citations	Relevance
A survey of socially interactive robots	T Fong, I Nourbakhsh, K Dautenhahn	2003	2080	138.67
On learning, representing, and generalizing a task in a humanoid robot	S Calinon, F Guenter, A Billard	2007	744	67.64
Human-robot interaction: a survey	MA Goodrich, AC Schultz	2007	743	67.55
Emotion and sociable humanoid robots	C Breazeal	2003	824	54.93
Human-robot interactions during the robot-assisted urban search and rescue response at the world trade center	J Casper, RR Murphy	2003	820	54.67
Robots for use in autism research	B Scassellati, H Admoni	2012	314	52.33
Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots	C Bartneck, D Kulić, E Croft, S Zoghbi	2009	445	49.44
Socially intelligent robots: dimensions of human–robot interaction	K Dautenhahn	2007	450	40.91
Toward sociable robots	C Breazeal	2003	598	39.87
Human-robot interaction in rescue robotics	RR Murphy	2004	531	37.93
Common metrics for human-robot interaction	A Steinfeld, T Fong, D Kaber, M Lewis, MA Goodrich, AC Schultz	2006	453	37.75
Anthropomorphism and the social robot	BR Duffy	2003	524	34.93
An atlas of physical human–robot interaction	A De Santis, B Siciliano, A De Luca, A Bicchi	2008	342	34.20
Robotic assistants in therapy and education of children with autism: can a small humanoid robot help encourage social interaction skills?	B Robins, K Dautenhahn, R Te Boekhorst	2005	432	33.23
Defining socially assistive robotics	D Feil-Seifer, MJ Mataric	2005	431	33.15
Defining socially assistive robotics	D Feil-Seifer, MJ Mataric	2005	427	32.85
Service robots in the domestic environment: a study of the roomba vacuum in the home	J Forlizzi	2006	339	28.25
Service robots in the domestic environment: a study of the roomba vacuum in the home	J Forlizzi, C DiSalvo	2006	325	27.08

Socially assistive robots in elderly care: A systematic review into effects and effectiveness	R Bemelmans, GJ Gelderblom, P Jonker	2012	158	26.33
What is a robot companion-friend, assistant or butler?	K Dautenhahn, S Woods, C Kaouri	2005	341	26.23
Social robots as embedded reinforcers of social behavior in children with autism	ES Kim, LD Berkovits, EP Bernier, D Leyzberg	2013	127	25.40
Living with seal robots—its sociopsychological and physiological influences on the elderly at a care house	K Wada, T Shibata	2007	264	24.00
Socially assistive robotics	A Tapus, MJ Mataric	2007	262	23.82
Socially assistive robotics	A Tapus, MJ Mataric	2007	259	23.55
Social interactions in HRI: the robot view	C Breazeal	2004	323	23.07
KASPAR—a minimally expressive humanoid robot for human–robot interaction research	K Dautenhahn, CL Nehaniv, ML Walters	2009	204	22.67
Effects of nonverbal communication on efficiency and robustness in human-robot teamwork	C Breazeal, CD Kidd, AL Thomaz	2005	294	22.62
How to build robots that make friends and influence people	C Breazeal, B Scassellati	1999	419	22.05
Using socially assistive human–robot interaction to motivate physical exercise for older adults	J Fasola, MJ Mataric	2012	132	22.00
From isolation to communication: a case study evaluation of robot assisted play for children with autism with a minimally expressive humanoid robot	B Robins, K Dautenhahn	2009	195	21.67
An ethological and emotional basis for human–robot interaction	RC Arkin, M Fujita, T Takagi, R Hasegawa	2003	298	19.87
Moonlight in Miami: Field study of human-robot interaction in the context of an urban search and rescue disaster response training exercise	JL Burke, RR Murphy, MD Coovert	2004	271	19.36
A sociable robot to encourage social interaction among the elderly	CD Kidd, W Taggart, S Turkle	2006	223	18.58
Recognizing engagement in human-robot interaction	C Rich, B Ponsler, A Holroyd	2010	148	18.50
Beyond usability evaluation: Analysis of human-robot interaction at a major robotics competition	HA Yanco, JL Drury, J Scholtz	2004	254	18.14
Designing robots for long-term social interaction	R Gockley, A Bruce, J Forlizzi	2005	229	17.62

Theory and evaluation of human robot interactions	J Scholtz	2003	263	17.53
Theory and evaluation of human robot interactions	J Scholtz	2003	261	17.40
Recognition of affective communicative intent in robot-directed speech	C Breazeal, L Aryananda	2002	267	16.69
Awareness in human-robot interactions	JL Drury, J Scholtz, HA Yanco	2003	248	16.53
Automatic analysis of affective postures and body motion to detect engagement with a game companion	J Sanghvi, G Castellano, I Leite	2011	115	16.43
“Robovie, you'll have to go into the closet now”: Children's social and moral relationships with a humanoid robot.	PH Kahn Jr, T Kanda, H Ishiguro, NG Freier	2012	97	16.17
Human-robot proxemics: physical and psychological distancing in human-robot interaction	J Mumm, B Mutlu	2011	113	16.14
Metrics for evaluating human-robot interactions	DR Olsen, MA Goodrich	2003	242	16.13
An affective guide robot in a shopping mall	T Kanda, M Shiomi, Z Miyashita	2009	144	16.00
Robots in organizations: the role of workflow, social, and environmental factors in human-robot interaction	B Mutlu, J Forlizzi	2008	158	15.80
How robotic products become social products: an ethnographic study of cleaning in the home	J Forlizzi	2007	173	15.73
The role of expressiveness and attention in human-robot interaction	A Bruce, I Nourbakhsh	2002	246	15.38
The role of expressiveness and attention in human-robot interaction	A Bruce, I Nourbakhsh	2002	246	15.38
The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment	ML Walters, K Dautenhahn	2005	196	15.08
Can robots manifest personality?: An empirical test of personality recognition, social responses, and social presence in human–robot interaction	KM Lee, W Peng, SA Jin, C Yan	2006	178	14.83
Methodology & themes of human-robot interaction: A growing research field	K Dautenhahn	2007	162	14.73
Classifying human-robot interaction: an updated taxonomy	HA Yanco, J Drury	2004	204	14.57
Socially assistive robotics for post-stroke rehabilitation	MJ Matarić, J Eriksson	2007	157	14.27
Robots at home: Understanding long-term human-robot interaction	CD Kidd, C Breazeal	2008	142	14.20

"My Roomba is Rambo": intimate home appliances	JY Sung, L Guo, RE Grinter, HI Christensen	2007	154	14.00
A two-month field trial in an elementary school for long-term human–robot interaction	T Kanda, R Sato, N Saiwaki	2007	153	13.91
Physical relation and expression: Joint attention for human-robot interaction	M Imai, T Ono, H Ishiguro	2003	208	13.87
Investigating joint attention mechanisms through spoken human–robot interaction	M Staudte, MW Crocker	2011	92	13.14
Socially assistive robotics	MJ Matarić, B Scassellati	2016	26	13.00
Prediction of human behavior in human–robot interaction using psychological scales for anxiety and negative attitudes toward robots	T Nomura, T Kanda, T Suzuki	2008	126	12.60
The domesticated robot: design guidelines for assisting older adults to age in place	JM Beer, CA Smarr, TL Chen, A Prakash, TL Mitzner, CC Kemp	2012	73	12.17
A design-centred framework for social human-robot interaction	C Bartneck, J Forlizzi	2004	168	12.00
Investigating spatial relationships in human-robot interaction	H Hüttenrauch, KS Eklundh, A Green	2006	144	12.00
The effect of presence on human-robot interaction	WA Bainbridge, J Hart, ES Kim	2008	120	12.00
Affective state estimation for human–robot interaction	D Kulic, EA Croft	2007	129	11.73
Conversational gaze aversion for humanlike robots	S Andrist, XZ Tan, M Gleicher, B Mutlu	2014	46	11.50
Are physically embodied social agents better than disembodied social agents?: The effects of physical embodiment, tactile interaction, and people's loneliness in human–robot interaction	KM Lee, Y Jung, J Kim, SR Kim	2006	134	11.17
Robot-assisted wayfinding for the visually impaired in structured indoor environments	V Kulyukin, C Gharpure, J Nicholson, G Osborne	2006	134	11.17
Robot-assisted wayfinding for the visually impaired in structured indoor environments	V Kulyukin, C Gharpure, J Nicholson, G Osborne	2006	134	11.17
Evaluating human-robot interaction	JE Young, JY Sung, A Volda, E Sharlin	2011	77	11.00

Final report for the DARPA/NSF interdisciplinary study on human-robot interaction	JL Burke, RR Murphy, E Rogers	2004	147	10.50
Seven principles of efficient human robot interaction	MA Goodrich, DR Olsen	2003	138	9.20
Do people hold a humanoid robot morally accountable for the harm it causes?	PH Kahn Jr, T Kanda, H Ishiguro, BT Gill, JH Ruckert, S Shen, HE Gary	2012	54	9.00
Experiences with Sparky, a social robot	M Scheeff, J Pinto, K Rahardja, S Snibbe	2002	144	9.00
Robots in the wild: Observing human-robot social interaction outside the lab	S Sabanovic, MP Michalowski	2006	107	8.92
Design patterns for sociality in human-robot interaction	PH Kahn, NG Freier, T Kanda, H Ishiguro	2008	87	8.70
Human-robot collaboration: a survey	A Bauer, D Wollherr, M Buss	2008	87	8.70
The robot museum robot installations: A five year experiment	IR Nourbakhsh, C Kunz	2003	130	8.67
First steps toward natural human-like HRI	M Scheutz, P Schermerhorn, J Kramer, D Anderson	2007	94	8.55
Benchmarks for evaluating socially assistive robotics	D Feil-Seifer, K Skinner, MJ Matarić	2007	93	8.45
A conversational robot in an elderly care center: an ethnographic study	AM Sabelli, T Kanda, N Hagita	2011	59	8.43
Interactions with a moody robot	R Gockley, J Forlizzi, R Simmons	2006	101	8.42
Interactions with a moody robot	R Gockley, J Forlizzi, R Simmons	2006	101	8.42
PARO robot affects diverse interaction modalities in group sensory therapy for older adults with dementia	S Sabanovic, CC Bennett, WL Chang	2013	41	8.20
Housewives or technophiles?: understanding domestic robot owners	JY Sung, RE Grinter, HI Christensen	2008	79	7.90
Anthropomorphism and human likeness in the design of robots and human-robot interaction	J Fink	2012	46	7.67
The application of robotics to a mobility aid for the elderly blind	G Lacey, KM Dawson-Howe	1998	147	7.35
Which robot behavior can motivate children to tidy up their toys?: Design and evaluation of ranger	J Fink, S Lemaignan, P Dillenbourg	2014	29	7.25

APPENDIX B – MAJA J MATARIĆ THOUGHT ON SAR FOR THE BLIND

2017-6-14

Gmail - SAR for the blind



Gilvan Gomes <gilgomes.r@gmail.com>

SAR for the blind

Maja Mataric <mataric@usc.edu>
 Para: Gilvan Gomes <gilgomes.r@gmail.com>
 Cc: Maja Mataric <mataric@usc.edu>

14 de junho de 2017 01:21

Hi Gilvan,

I love seeing motivated student, but most especially those motivated to help people with special needs! So keep that going!

Good question about SAR for the blind. There has been past robotics (not SAR, pre-SAR) work on guide canes and smart canes for the blind; I remember liking that work but I don't know how far it has gotten on the commercial market. It's most definitely a worthy cause. But what you are saying is something different. I think SAR for the blind would be really a great idea, especially if you combine some functional uses for the robot as well as motivational ones. In fact, I like it so much I think it's worth pursuing!

<>Maja

On Jun 13, 2017, at 8:27 PM, Gilvan Gomes <gilgomes.r@gmail.com> wrote:

> Hello professor Mataric!
 >
 > I'm a Computer Science student from Brazil, a big fan of your work, and I'm currently working on research on the assistive robotics field, and getting into the socially assistive robotics field now. What an awesome field of study!
 >
 > I know you are very busy and I don't want to take much of your time (though I'm doing it already, right?), so I have a very simple question for you.
 >
 > I've noticed there's not many research in SAR regarding visually impaired people. Do you think there's "room" for visually impaired people in the SAR area? I work with blind people and sometimes I get the sense that they too could use some help from a "socially interactive" (assistive) robot as to engage more and feel more motivated in their tasks, but that's just an opinion from an undergraduate student.
 >
 > Thank you so much for your time!
 > Gilvan Gomes

Source: Elaborated by the author.

APPENDIX C – JD PROGRAMMING SCRIPT

```

1  $shouldPlayThroughEZB=1
2
3  $nomeDoParticipante="João"
4  IF ($shouldPlayThroughEZB)
5      $camera="cabeça"
6  ELSE
7      $camera="câmera"
8  ENDIF
9  $bebidaescolhida="Entendi. Agora que você escolheu o sabor, vou lhe ajudar a
identificar o potinho com a bebida correta. Você tem as cápsulas com os diferentes
sabores na sua frente. Você deve pegar um deles, encontrar minha "+ $camera +" e
aproximar a parte plana da cápsula a uns 20 centímetros dela. Vou lhe informar assim
que reconhecer a bebida."
10
11 ControlCommand("Bing Speech Recognition", PauseListening)
12
13 IF ($saborescolhido != "nenhum")
14     IF (Contains($BingSpeech, "trocar"))
15         $tts = "Certo. Lembrando que temos café com leite, expresso, e nescau. Qual você
prefere?"
16         ControlCommand("Test Plugin", StartPlayingAudio)
17         $saborescolhido = "nenhum"
18         $CameraObjectName = ""
19
20         $EZBPlayingAudio = 1
21         WaitFor($EZBPlayingAudio = 0)
22     ELSEIF (Contains($BingSpeech, "continuar"))
23         $tts = "Agora você pode iniciar a preparação seguindo as orientações que você
recebeu sobre o uso da máquina, mas posso lhe dar instruções caso você precise. Se
você precisar de instruções, me diga que deseja instruções, caso contrário, diga,
terminei."
24         ControlCommand("Test Plugin", StartPlayingAudio)
25
26         $EZBPlayingAudio = 1
27         WaitFor($EZBPlayingAudio = 0)
28     ELSEIF (Contains($BingSpeech, "instruções"))
29         $tts = "Para começar a preparação, você deve abrir a tampa frontal da máquina e
encaixar o potinho lá dentro. Depois feche a tampa. Caso você necessite de mais
instruções para a próxima etapa, diga, fechei a tampa, e lhe darei novas instruções."
30         ControlCommand("Test Plugin", StartPlayingAudio)
31
32         $EZBPlayingAudio = 1
33         WaitFor($EZBPlayingAudio = 0)
34     ELSEIF (Contains($BingSpeech, "tampa"))
35         $tts = "Agora puxe a alavanca para a direita. Assim que ouvir o barulho de que
terminou a água, puxe a alavanca para o meio novamente e aguarde 10 segundos, antes
de retirar a xícara do lugar. Enquanto estiver aguardando os 10 segundos, me diga
que está aguardando."
36         ControlCommand("Test Plugin", StartPlayingAudio)
37
38         $EZBPlayingAudio = 1
39         WaitFor($EZBPlayingAudio = 0)
40     ELSEIF (Contains($BingSpeech, "aguardando") || Contains($BingSpeech, "terminei"))
41         $tts = "Aproveite sua bebida, " + $nomeDoParticipante + ", mas tenha cuidado, pois
ela estará bem quente! Espero que você tenha gostado da minha ajuda! Tenha um
excelente dia!"
42         ControlCommand("Test Plugin", StartPlayingAudio)
43
44         $EZBPlayingAudio = 1
45         WaitFor($EZBPlayingAudio = 0)
46     ELSEIF (Contains($BingSpeech, "repetir"))
47         $novotts = "Repetindo... " + $tts
48         $tts = $novotts
49         ControlCommand("Test Plugin", StartPlayingAudio)
50
51         $EZBPlayingAudio = 1
52         WaitFor($EZBPlayingAudio = 0)
53     ELSE
54         $tts = "Não entendi o que você falou. Pode repetir, por favor?"

```

```

55     ControlCommand("Test Plugin", StartPlayingAudio)
56
57     $EZBPlayingAudio = 1
58     WaitFor($EZBPlayingAudio = 0)
59 ENDIF
60
61 ELSEIF (Contains($BingSpeech, "começar"))
62     $tts = "Olá " + $nomeDoParticipante + "! Vou lhe ajudar a preparar uma bebida. Temos
        três opções, café com leite, expresso, e nescau. Qual você prefere?"
63     ControlCommand("Test Plugin", StartPlayingAudio)
64
65     $EZBPlayingAudio = 1
66     WaitFor($EZBPlayingAudio = 0)
67 ELSEIF (Contains($BingSpeech, "expresso") || Contains($BingSpeech, "leite") || Contains(
        $BingSpeech, "nescau"))
68     $tts = $bebidaescolhida
69     ControlCommand("Test Plugin", StartPlayingAudio)
70
71     $EZBPlayingAudio = 1
72     WaitFor($EZBPlayingAudio = 0)
73
74     IF (Contains($BingSpeech, "expresso"))
75         $saborescolhido = "EXPRESSO"
76     ELSEIF (Contains($BingSpeech, "leite"))
77         $saborescolhido = "CAFE AO LEITE"
78     ELSEIF (Contains($BingSpeech, "nescau"))
79         $saborescolhido = "NESCAU"
80     ENDIF
81
82     ControlCommand("Camera", CameraStart)
83
84     REPEATWHILE ($CameraObjectName != $saborescolhido)
85         $CameraHorizontalQuadrant = "Unknown"
86         $CameraObjectName = ""
87
88         WaitForChange($CameraObjectName, 20000)
89
90         IF ($CameraHorizontalQuadrant = "Unknown")
91             $tts = "Não identifiquei o sabor. Coloque o potinho mais ou menos uns 20
                centímetros de minha " + $camera + ", por favor, que vou continuar identificando
                a cápsula."
92             ControlCommand("Test Plugin", StartPlayingAudio)
93             $EZBPlayingAudio = 1
94             WaitFor($EZBPlayingAudio = 0)
95             ELSEIF ($CameraHorizontalQuadrant != "Unknown")
96                 IF ($CameraObjectName = $saborescolhido)
97                     $tts = "Você pegou o potinho do " + $saborescolhido + ", o sabor que você
                        escolheu anteriormente! Se deseja trocar a bebida, diga, quero trocar, caso
                        contrário diga, continuar."
98                     ControlCommand("Test Plugin", StartPlayingAudio)
99                     $EZBPlayingAudio = 1
100                    WaitFor($EZBPlayingAudio = 0)
101                ELSE
102                    $tts = "Este sabor é o " + $CameraObjectName
103                    ControlCommand("Test Plugin", StartPlayingAudio)
104                    $EZBPlayingAudio = 1
105                    WaitFor($EZBPlayingAudio = 0)
106                ENDIF
107            ENDIF
108        ENDREPEATWHILE
109
110        ControlCommand("Camera", CameraStop)
111
112        ELSEIF (Contains($BingSpeech, "repetir"))
113            $novotts = "Repetindo... " + $tts
114            $tts = $novotts
115            ControlCommand("Test Plugin", StartPlayingAudio)
116
117            $EZBPlayingAudio = 1

```

```
118     WaitFor($EZBPlayingAudio = 0)
119 ELSE
120     $tts = "Não entendi o que você falou. Pode repetir, por favor?"
121     ControlCommand("Test Plugin", StartPlayingAudio)
122
123     $EZBPlayingAudio = 1
124     WaitFor($EZBPlayingAudio = 0)
125 ENDIF
126
127 ControlCommand("Bing Speech Recognition", UnpauseListening)
128
```

APPENDIX D – QUESTIONNAIRES BASED ON THE GODSPEED SERIES

Questionário Experimento - Robô

*Obrigatório

1. Nome do participante *

2. Godspeed I - Antropomorfismo - Falso/Natural *

Por favor, avalie a sua impressão sobre as características humanas do robô nas seguintes escalas:
Marcar apenas uma oval.

	1	2	3	4	5	
Falso	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Natural

3. Godspeed I - Antropomorfismo - Aspecto *

Marcar apenas uma oval.

	1	2	3	4	5	
Com aspeto mecânico	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Com aspeto humano

4. Godspeed I - Inconsciente/Consciente *

Marcar apenas uma oval.

	1	2	3	4	5	
Inconsciente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Consciente

5. Godspeed I - Artificial/Vivo *

Marcar apenas uma oval.

	1	2	3	4	5	
Artificial	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Parece Vivo

6. Godspeed II - Expressão de vida - Morto/Com vida *

Por favor, avalie a sua impressão sobre a expressão de vida do robô nas seguintes escalas:
Marcar apenas uma oval.

	1	2	3	4	5	
Morto	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Com vida

7. Godspeed II - Apático/Participativo *

Marcar apenas uma oval.

	1	2	3	4	5	
Apático	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Participativo

8. Godspeed III - Simpatia - Gosta/Não gosta *

Por favor, avalie a sua impressão sobre a simpatia do robô nas seguintes escalas:
Marcar apenas uma oval.

	1	2	3	4	5	
Não gosto	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Gosto

9. Godspeed III - Hostil/Amigável *

Marcar apenas uma oval.

	1	2	3	4	5	
Hostil	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Amigável

10. Godspeed III - Antipático/Gentil *

Marcar apenas uma oval.

	1	2	3	4	5	
Antipático	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Gentil

11. Godspeed III - Desagradável/Agradável *

Marcar apenas uma oval.

	1	2	3	4	5	
Desagradável	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Agradável

12. Godspeed III - Horrível/Simpático *

Marcar apenas uma oval.

	1	2	3	4	5	
Horrível	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Simpático

13. Godspeed IV - Inteligência Percebida - Ignorante/Sábio *

Por favor, avalie a sua impressão sobre a inteligência percebida do robô nas seguintes escalas:
Marcar apenas uma oval.

	1	2	3	4	5	
Ignorante	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Sábio

14. Godspeed IV - Irresponsável/Responsável *

Marcar apenas uma oval.

	1	2	3	4	5	
Irresponsável	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Responsável

15. Godspeed IV - Não inteligente/Inteligente *

Marcar apenas uma oval.

	1	2	3	4	5	
Não inteligente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Inteligente

16. Godspeed IV - Insensato/Sensato *

Marcar apenas uma oval.

	1	2	3	4	5	
Insensato	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Sensato

17. Godspeed V - Segurança Percebida - Ansioso/Descontraído *

Por favor, avalie o seu estado emocional sobre a segurança percebida do robô nas seguintes escalas:
Marcar apenas uma oval.

	1	2	3	4	5	
Ansioso	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Descontraído

18. Godspeed V - Agitado/Calmos *

Marcar apenas uma oval.

	1	2	3	4	5	
Agitado	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Calmos

19. Godspeed V - Sereno/Surpreso *

Marcar apenas uma oval.

	1	2	3	4	5	
Sereno	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Surpreso

20. Presença social - A *

Por favor, avalie as seguintes afirmações utilizando as seguintes escalas. Afirmação: Eu considero o robô um parceiro conversacional agradável.
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Concordo totalmente

21. Presença social - B *

Ao interagir com o robô, eu senti como se estivesse falando com uma pessoa real.
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Concordo totalmente

22. Presença social - C *

Às vezes, o robô parecia ter sentimentos reais.
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Concordo totalmente

23. Confiança *

Eu me senti seguro interagindo com o robô.
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Concordo totalmente

24. Diálogo - A *

Eu entendi o que o robô disse.
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Concordo totalmente

25. Diálogo - B *

O robô entendeu o que eu disse.
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Concordo totalmente

26. Esta é a segunda interação? *

Marcar apenas uma oval.

- Sim *Ir para a pergunta 27.*
 Não *Pare de preencher este formulário.*

Pare de preencher este formulário.

Finalização do estudo

27. Você preferiu interagir com: *

Marcar apenas uma oval.

- Computador
 Robô
 Indiferente

28. Por quê?

29. Algum comentário sobre a interação?

APPENDIX E – ARTICLE SUBMITTED TO THE HRI CONFERENCE 2018

Socially Assistive Robotics for the Blind: Evaluation of a Small Humanoid Robot

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Abstract. *The Socially Assistive Robotics (SAR) field studies how robots can help humans through social rather than physical interaction. It may seem contrary to common sense expectation that physical robots can be used for social assistance, as one could just use software agents or other devices in order to do that. Researchers point out, however, that humans tend to attribute life-like characteristics to robots and to socially engage with them, as they are embodied agents that have enough biological-like motion or appearance aspects. In this case, people commonly engage with physical machines, projecting intentions, goals, and emotions to them. In this study we have investigated, through a short-term experiment, blind persons perceptions of a physically collocated robot compared to a regular computer in regard to functional and social aspects. Results show that, in general, participants preferred to interact with the robot, demonstrating interest and being more engaged. In addition, our findings suggest that the physical embodiment evokes a positive attitude from the blind persons towards the robot, even when the physical capabilities of the robot are not explored.*

1. Introduction

Human-Robot Interaction (HRI) is an area committed to understanding, designing, and evaluating robotic systems that work together with people. Socially Interactive Robots is a branch of HRI which focuses on robots to which human-robot social interaction is relevant [Fong et al. 2003]. Finally, Socially Assistive Robotics (SAR) comprehends social robots that are also assistive, concentrating on helping human users through social instead of physical interaction [Feil-Seifer and Mataric 2005].

SAR shares with assistive robotics the objectives to give assistance to humans, but presenting a whole new series of research challenges. Once it is understood how robots can interact with people, they can effectively and measurably help in the processes of recovery, rehabilitation, socialization, training, and education. It may seem counterintuitive that physical robots can be used for social assistance, as software agents or other devices could be simpler options for that. However, research has shown that humans tend to attribute life-like characteristics to machines and to socially engage with them, especially

robots, as they are embodied agents that have enough biological-like motion or appearance characteristics. People are used to engaging with physical machines, projecting intentions, goals, and emotions to them [Mataric et al. 2007, Tapus et al. 2007].

Social behavior acts as a key role in assisting humans. Additionally, it seems even more important for people with special needs. The robot's physical embodiment, presence and appearance, and the robot's shared environment with the user are essential for creating a long-term engaging relationship. To establish a very complex and complete human-robot relationship, robots should exhibit human-oriented interaction skills and capacities, showing context awareness and social behavior that matches the needs of the user. In order to help the user achieve specific objectives, robots should focus attention and communications on the user [Tapus et al. 2007].

Blind persons face many challenges in their daily activities, from finding their way to the right bus stop to identifying the actual bus they should take. While technology has been used to help people with disabilities in a variety of different and efficient ways, blind people still have many needs to be addressed [Brady et al. 2013]. Assistive robots have been considered to fulfill some of these demands, specially those regarding indoor navigation [Kulyukin et al. 2004, Kulkarni et al. 2016]. Despite having important aspects of HRI, these robots usually demonstrate little or none social interaction characteristics as they are more focused on the functional side of the robots.

Although some researchers have found a more positive attitude from people of various different backgrounds towards embodied collocated robots [Powers et al. 2007, Robins et al. 2004] rather than a computer agent, the literature about whether using a robot or an agent makes any difference for a specific task for blind persons is scarce. As the interaction between humans and robots typically starts with the human seeing the robot, the appearance (e.g., size and posture) of a robot significantly impacts first initial impressions of sighted individuals and the consequent interaction [Min et al. 2015]. Therefore, blind persons perception of the robot might be different from that of a sighted individual.

One could argue that a physical embodiment is not important to a blind individual as that seems to be something only a sighted person would enjoy and perceive. Philosophers, however, have discussed how blind people actually "see" with their hands since the 18th century [Paterson 2006]. These discussions try to understand the link between the senses and cognition. In our case, even though blind people perception might be different from that of a sighted person, they could still sense the embodiment of the robot.

The goal of this paper is to explore the attitudes of blind people towards a small socially assistive humanoid robot, focusing on which aspects of the robot's design can contribute to their engagement in the interaction, paying special attention to the robot's anthropomorphism. Using a short experiment, we tested whether the participants will prefer to interact with a robot, as it is anthropomorphically embodied, or with a laptop, which is only functionally embodied.

The following sections of this paper are organized as follows. In the next section, we present related work in the area of socially assistive robotics for blind persons. Section 3 describes main assumptions, hypotheses and research method that we have employed in the experiment. In Section 4, we discuss preliminary results and evaluate the perceptions

of blind persons about the distinct interactions. We conclude the paper with a summary of the key research contributions of this work.

2. Background and Related Work

2.1. Socially Assistive Robotics

Assistive robotics is an area dedicated to aid or support human users in a variety of different situations, usually involving physical interaction, whereas socially interactive robots are those that focus on social human–robot interaction. SAR is defined as the intersection of assistive robotics and socially interactive robotics, specifying that robots should assist human users by means of social interaction rather than by physical contact [Feil-Seifer and Mataric 2005]. Thus, SAR is characterized as a way to help human users with special needs in their daily activities, having the possibility to enhance the quality of life of many individuals with different needs [Tapus et al. 2007]. Such users include individuals with cognitive disabilities or those going through physical rehabilitation as well as the elderly.

One of the main focus of SAR has been autistic children therapy. Robots have been used to capture and maintain attention, to stimulate joint attention and imitation, and to mediate turn-taking [Scassellati et al. 2012]. In addition, robots have been observed being used as mediators for the children’s interactions with their teachers [Robins et al. 2005], allowing the children to share their experience with the researcher and with their caregiver.

Post-stroke rehabilitation is also an application domain of SAR. [Matarić et al. 2007] states that patients seem to follow their rehabilitation exercises more regularly with the help of robots, since they share the physical context and physical movement of the robot and are encouraged to exercise, as well as having continuous monitoring.

Another goal of SAR is to extend independent living for the elderly and to create companions that attempt to reduce stress and depression. Studies with elderly people have shown that they became more friendly to their caregiver and more socially communicative, in addition to laughing and smiling more [Matarić et al. 2007]. Robotic animal toys such as AIBO and PARO have been used to improve physiological and psychological health in elderly patients. The robotic seal PARO has been shown to promote engagement between older adults with cognitive impairment, comprising many aspects of social interaction, such as visual, verbal, and physical interaction [Sabanovic et al. 2013].

A common design issue discussed in most SAR studies is the robot’s embodiment, as it affects not only their physical presence but also cooperation [Tapus et al. 2007].

2.2. Embodiment

[Dautenhahn et al. 2002, p. 400] defines embodiment as ”that which establishes a basis for structural coupling by creating the potential for mutual perturbation between system and environment.” Thus, embodiment is linked to the connection between the system and its environment.

[Fong et al. 2003] classifies social robots’ embodiment in four broad categories: anthropomorphic, zoomorphic, caricatured, and functional. They state that social robots

can be classified under any of these categories and that these robots do not need a physical body, as other agents such as conversational ones might differ from robots only in its actuation.

However, some studies have compared physical robots with computer agents and showed differences in the users' perception. In a study with 113 participants comparing a collocated robot, a robot projected on a big screen and an agent on a computer screen, [Powers et al. 2007] showed that people liked the robot more than the agents. In addition, they observed that the kind of robot to be chosen depends on the task to be executed. Moreover, tasks that are more relationship-oriented seem to work better with a collocated robot.

Similarly, [Seo et al. 2015] compared empathy toward a physical and a simulated robot and showed that people may empathize more with a real robot than with a simulated one when bad things happen to it.

Literature shows that even the very simple machines with life-like form or movement are associated with goals, emotions, personalities and objectives by humans [Tapus et al. 2007, Forlizzi 2007]. This anthropomorphism, however, is usually said to be necessary for a meaningful social interaction [Fong et al. 2003], as robots should interact with humans in a similar way as that of humans interacting with humans. Therefore, anthropomorphism has the purpose of working as a mechanism to facilitate social interaction [Fong et al. 2003].

[Li et al. 2010] used an anthropomorphic, a zoomorphic and a functional (machine-like) robot in their study. They found significant differences in the attitude towards these robots from people with different backgrounds. Nonetheless, they state that even slightly humanoid features might be enough to increase people's familiarity to robots and therefore result in an elevated likeability. Yet, [Robins et al. 2004] showed that autistic children initially preferred a robot with its plain robotic appearance over a robotic doll dressed like a human (a 'pretty doll' appearance).

These studies indicate that different groups of users have different perspectives and opinions towards the embodiment of robots, even though humanoid robots are usually preferred by most groups studied. Therefore, research with different groups is needed in order to evaluate their perception of a robot's embodiment. Blind persons is one of these groups that have yet to be tested working closely with social robots and, thus, their perception of said interactions needs further investigation.

2.3. Blind People and Assistive Robotics

Assistive robotics usually involves physical interaction. In the context of blind people's needs, some research on independence granting robots has been done, specially for mobility-oriented tasks. [Gharpure and Kulyukin 2008] have developed a robotic platform aimed at independent shopping. Similarly, other researchers have worked on robot-assisted wayfinding and indoor navigation [Kulyukin et al. 2006, Kulkarni et al. 2016].

Help for locomotion can not only make blind persons more independent, but also help them to exercise either by just walking or allowing them to visit places where they can find other activities. Studies have shown that low-vision or blind persons are more prone to obesity than people who are sighted [Capella-McDonnall 2007]. Some promis-

ing non-robotic technology has been used to help the former to exercise [Rector 2017]. Similarly, SAR has been used to motivate people to exercise more with encouraging results [Fasola and Mataric 2012, Kidd and Breazeal 2008].

While studying social robots, [Kidd and Breazeal 2008] showed in a long-term study that participants developed a close relationship to a robotic weight loss coach and kept record of their calorie consumption, exercising almost twice as long when using the robot compared to the other methods used in the study (a standalone computer and a traditional paper log). Thus, social robots could be used in the future to motivate blind persons to exercise more as well.

Furthermore, robots could have their functional side combined with motivational ones, as the range of assistance options blind persons could get from a robot is enormous. However, in order to use robots to help the blind in social interaction-oriented tasks, it is necessary to understand the users' impressions towards these robots, as they might be different from those of sighted individuals.

3. Experiment

As blind persons face many challenges in their everyday lives, robots could be used to help them in a variety of different ways. Combining functional tasks of robotic systems used for wayfinding or indoor navigation with social interaction is just one of the many options. However, before turning these assistive robots into socially assistive ones, we need to understand how the design issues in social robots research impacts robot-human interaction for the blind.

As a first step towards actually using SAR for the blind, it is necessary to comprehend their needs and impressions of social robots, as blind persons are getting an ever increasing amount of help from assistive technology.

As one of the key role in the robot's assistive effectiveness [Tapus et al. 2007], we chose to analyze the physical embodiment of our agent, leaving aside other factors for future studies. As anthropomorphism is usually preferred when it comes to having a meaningful social interaction [Fong et al. 2003], we decided to use a physical collocated humanoid robot, a regular laptop, and to compare blind persons' reaction to them.

The objective of this experiment is to test whether the participants will prefer to interact with a robot, as it is anthropomorphically embodied, or with a laptop, which is only functionally embodied, after executing the same task with both. We designed an experiment with a within-subject study design, where the robot and the laptop helped blind participants to prepare a beverage through vocal instructions.

The robot and the laptop were able to identify the beverage the participant was holding, as well as being able to give instructions on how to operate a coffee machine. This is important, as only a sighted person can identify without assistance the capsules (or "pods") the machine uses for coffee making. Two sessions were conducted with each participant, in two different and non-consecutive days. In the first interaction, randomly-assigned participants interacted with the robot and the others with the computer. In the second interaction, those who interacted with the robot interacted with the computer and vice versa.

Our hypothesis are as follows:

- **H1:** Participants will prefer to interact with the robot;
- **H2:** Participants will perceive the robot as more naturalistically embodied than the computer;
- **H3:** Participants will perceive the robot as more alive than the computer;
- **H4:** Participants will perceive both systems as intelligent;
- **H5:** Participants will feel equally calm while using both systems;

3.1. The systems

We use the word *system* here meaning either the robot or the computer and all what is related to it during the experiment (e.g. coffee machine, voice recognition, etc).

3.1.1. The robot

The robotic agent used in our experiment was Revolution JD, from EZ Robot. It is a low-cost, 33 cm tall humanoid robot with 16 degrees of freedom. JD has a camera on its head and a built-in speaker. It is intended to be used as an entertainment device as well as an educational tool, allowing researchers to dynamically adapt it to their needs.

JD's camera can be used for different computer vision tasks, such as recognizing faces, objects and colors. JD connects wirelessly to a computer which processes all the information through its software platform.

As assistive robots must efficiently display natural communicative performance that is not only adequate but engaging to its users [Tapus et al. 2007], we tried to make the process of communication as simple and effective as possible, but without spending a lot of time developing it.

Therefore, following the current trend in cloud robotics [Lorencik and Sincak 2013], we used cloud based services for voice recognition and text-to-speech. That allowed us to, without prior training, use a more natural voice and advanced speech recognition in the participants' language (Brazilian Portuguese in our case). Experiments with blind people have shown many complaints from participants regarding issues with speech recognition [Kulyukin et al. 2004]. Thus, a microphone placed on the user's clothing was used to enhance voice recognition.

A script in JD's software had a set of predefined grammar and the system would ask the participant to repeat if it did not recognize what was said. The grammar was designed to guide the participant's answers. For example, if the system asked the participant whether they wanted more instructions or not, it would say "Do you want more instructions? Please respond with yes or no."

3.1.2. The computer

The computer used in our experiment was a regular laptop. Thus, the only significant difference compared to the robot was the embodiment itself, with the laptop's camera being used for recognition. As JD's robotic voice differs from that of the computer, JD was left hidden behind the laptop, so when the software "spoke" to the participant it had

the same quality and volume as the robot. The participants were not told about this until the end of the experiment.

The idea behind this setting was to make both systems as similar as possible, leaving only the embodiment as a differing factor. The same softwares were used for voice and image recognition, and there was no difference in the wait time for recognition in either systems.

3.1.3. The coffee machine

Both systems helped the participant verbally by optionally giving instructions on how to operate the coffee machine but, most importantly, by recognizing what beverage the participant was holding. The coffee machine used in the experiment was a NESCAFÉ® Dolce Gusto®, which heats the water that is then passed at high pressure through a capsule of roasted ground coffee into the cup. It's a 15 bar system that uses pressure similar to coffee house machines, and each pod makes one beverage serving in under a minute [S.A. 2017]. However, neither the pods nor the original boxes come with braille information, so there's no way a blind individual can know what kind of beverage he/she is holding.

3.2. Method

3.2.1. Subjects

Participants were recruited by the staff at a non-governmental institution specialized in care and education for the blind. All participants were volunteers, gave their full consent, and were informed during the recruitment that they would be completing surveys and interacting with a small robot. Only people with congenital or acquired blindness were asked to participate. It was logistically difficult to acquire a large number of participants for the study. In fact, most studies with blind persons have a small number of participants (see [Gharpure and Kulyukin 2008] and [Mau et al. 2008]).

Although ten people took part on the first part of the study, a total of seven (N = 7) participants completed the whole experiment, ages ranging from 23 through 63. The other three participants could not get to the institution for the second part (reasons also included logistics problems).

3.2.2. Procedure

The participants' task was to autonomously prepare a beverage by only asking the robot for instructions.

On the first day, five people interacted with JD and two with the computer. One week later, they followed the same procedure, but the ones who had interacted with JD then completed the task with the help of the computer, and vice versa.

On the first interaction, each participant was brought into a room where they were welcomed by two researchers who discussed the experiment and the informed consent form. If the participant agreed to take part in the experiment, he/she was taught how to



Figure 1. The experiment setting

operate the coffee machine. Each participant sat at a table that had a computer, JD, the coffee machine and a little box with six randomly placed beverage pods, two from each flavor (the beverage options were espresso, coffee with milk, and chocolate milk), as seen in Figure 1. As the description of the robot might interfere in the user's perception of it [Min et al. 2015], participants had some time to freely touch the computer/JD and ask questions about their functionality.

One of the experimenters placed a plastic cup on the coffee machine at the beginning of the experiment and, later on, signaled when it was time for the participant to turn off the machine, as this specific version of the machine was not automated for this.

The participants were told that they could say "let's start" (in their native language) and the system would answer. Once the participant said that, the script was triggered on the software platform and the system greeted them and briefly explained what it could do. It then asked the participant to choose from the three types of beverages. The software then waited for the participant's decision. As soon as the participant said to the system which beverage they wanted, the system would tell the participant to start picking pods from the box and to place them about ten inches away from its camera, moving it slowly back and forth as the system would recognize the kind of beverage.

As soon as the system recognized the beverage, it asked the participant if they wanted to choose another flavor. If the answer was yes, it would repeat the process of choosing the beverage. If the answer was no, the system would tell the participant to start preparing the beverage, following the instructions previously given by the experimenter on how to operate the coffee machine. The system also offered to give complementary instructions if the participant needed, and if the answer was yes, it would go through the process of preparing the beverage, step by step. Once the participant told the system the beverage was ready, it would warn the participant that the cup's content was hot, tell them to enjoy the beverage and wish them a nice day. This would also occur if the participant had said they did not need help.



Figure 2. A participant interacting with JD

A participant interacting with JD can be seen in Figure 2.

3.3. Instruments

As soon as the interaction was over (i.e. the participant signaled that he/she had successfully prepared the beverage), each participant answered a series of questions. The questionnaire was based on the Godspeed series [Bartneck et al. 2009]. The exact same questionnaire was applied for both the first and second interactions. The only difference while asking the questions was on identifying the current system. For example, when the participant had interacted with the computer, the question *Please rate your impression of the robot on these scales* had the word *robot* replaced by *computer*, and so on.

Some questions were not included from the original questionnaire series due to translation considerations (questions that became too similar), or because they were related to movement (for example, the *Moving rigidly/Moving elegantly* question that belongs to the Anthropomorphism questionnaire).

Interviews were semi-structured as the participants were free to make observations about each answer if they wanted to. After each interaction, the same questions were made to each participant. At the end of the second interaction, the participants were asked if they preferred to interact with the robot, the computer, or if they liked both equally, and why they chose their answer.

Observations were made by one of the experimenters in the room in the form of notes. This was intended to help understand the aspects of the interaction, such as the participants gestures and reactions to either system.

4. Results

4.1. Robot vs. Computer

In order to test participants' answers, we used the Wilcoxon Signed-Rank Test. Many different tests are used in the general area of HRI, and as they all have different aspects, we

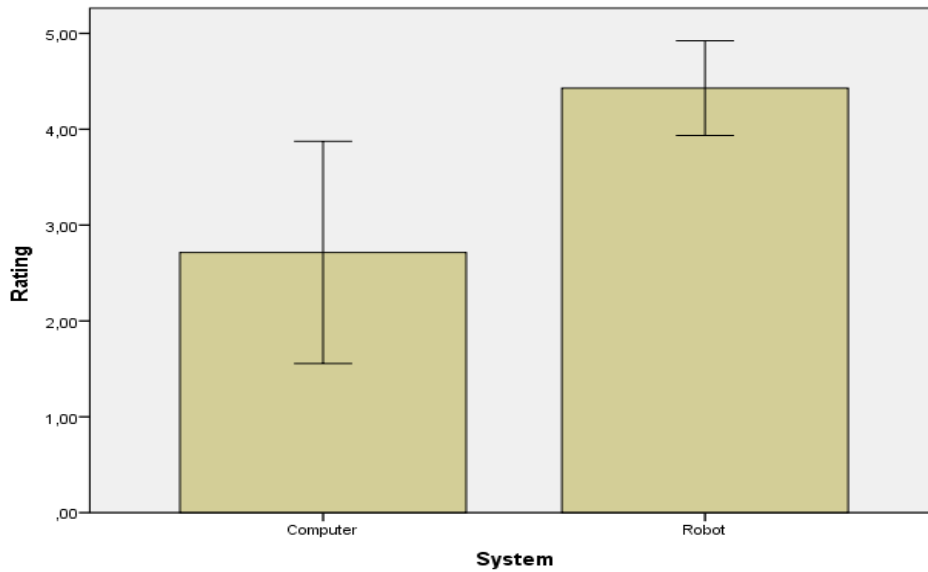


Figure 3. The average participant ratings for the Fake/Natural question.

had to analyze which one best suited our work. For example, in order to use the t-test of comparison between means of two paired samples, such samples must have normal distribution. As such assumption was violated in our study (confirmed by the Kolmogorov-Smirnov Normality test), the non-parametric Wilcoxon test was used. Bonferroni, another common test, is focused on multiple comparisons and it is used in Analysis of Variance (ANOVA), which, in turn, is also only used when the samples are normal. ANOVA compares means from three or more samples, which was not our case. Additionally, as we do not have many references to guide us on the specific topic of blind people using social robots, we followed methods used in the SAR area which also apply the Wilcoxon Signed-Rank test [Fasola and Mataric 2012].

The Fake/Natural question showed a statistically significant difference ($p < 0.05$), what supports Hypothesis 2, where we state that *participants will perceive the robot as more naturalistic embodied than the computer*. The average ratings for this question can be seen in Figure 3. The other questions regarding **Anthropomorphism** were Machine-like/Humanlike ($M_C = 2.43$, $M_R = 3.86$), Artificial/Lifelike ($M_C = 3.14$, $M_R = 4.00$), and Unconscious/Conscious ($M_C = 3.71$, $M_R = 3.71$). These questions did not have significant statistical differences ($p > 0.05$).

In the **Animacy** part of the questionnaire, there was no statistical difference in the Dead/Alive question, so Hypothesis 3, *participants will perceive the robot as more alive than the computer*, cannot be supported. The questions here were Dead/Alive ($M_C = 4.00$, $M_R = 4.00$) and Apathetic/Responsive ($M_C = 4.00$, $M_R = 4.71$).

The **Likeability** questions were Dislike/Like ($M_C = 4.29$, $M_R = 5.00$), Unfriendly/Friendly ($M_C = 4.43$, $M_R = 5.00$), Unkind/Kind ($M_C = 4.71$, $M_R = 5.00$), Awful/Nice ($M_C = 4.71$, $M_R = 4.86$), and Unpleasant/Pleasant ($M_C = 4.86$, $M_R = 4.86$). This does not statistically support our Hypothesis 1, *participants will prefer to interact with the robot*, but as described in section 4.3, the qualitative answers suggest preference for the robot.

When considering the **Perceived Intelligence** of the systems, the ratings had no statistical difference, being sometimes higher for the robot and sometimes higher for the computer, supporting our Hypothesis 4, *participants will perceive both systems as intelligent*. The questions were Incompetent/Competent ($M_C = 3.86$, $M_R = 3.71$), Irresponsible/Responsible ($M_C = 4.43$, $M_R = 4.29$), Unintelligent/Intelligent ($M_C = 3.86$, $M_R = 4.57$), and Foolish/Sensible ($M_C = 4.14$, $M_R = 4.43$).

No statistical differences were found between the two systems for the **Perceived Safety** questionnaire which includes the emotional state of participants. Questions asked if participants were Anxious/Relaxed ($M_C = 5.00$, $M_R = 4.00$) and Agitated/Calm ($M_C = 4.86$, $M_R = 4.00$). This supports our Hypothesis 5, *participants will feel equally calm while using both systems*. However, the ratings were higher for the computer in this case, suggesting that the robot made the participants feel more anxious and agitated. Whether that is due to the novelty effect is unclear.

4.2. Acquired vs. Congenital Blindness

We applied the Mann-Whitney Test to check differences in the answers from acquired and congenital blindness. No statistical differences were found, but we point out that the low number of participants in each group is not enough to make conclusions about the condition of the participants interfering in their perception of either system.

The same applies for the groups that either interacted with the computer or JD on the first day and that subsequently interacted with the other system.

4.3. Preference

After the second interaction, when asked what system participants preferred, 3 participants (42.9%) said they preferred to interact with JD, 1 said to prefer the computer (14.3%), and 3 said to like both equally (42.9%).

When asked to explain their answers, the following statements were given¹.

4.3.1. Preference for the Robot

P1: I preferred to interact with the robot because he² seems friendlier and has a body.

P3: The robot is very cool, the computer I am too accustomed to use. By being unusual, the robot becomes more interesting.

P5: I preferred to interact with the robot because he seems more human and smarter.

4.3.2. Preference for the Computer

P2: I prefer to interact with the computer because it is easier to carry around.

¹Freely translated.

²Unlike English, in Portuguese there's not such pronoun as "it" when referring to objects, so this is not to be seen as an indication that the participant is giving the robot a gender.

Participant P2 has an acquired blindness condition and demonstrated being opposed to ascribe human-like characteristics to JD from the beginning of the interview. Sometimes the participant explicitly argued about values of the Likert-scale for questions like Unconscious/Conscious and Dead/Alive, stating for both systems that it was very hard to answer that kind of question about a machine.

Some studies have found that cultural differences foster positive attitudes towards robots and people engagement with them [Li et al. 2010, Haring et al. 2014], what might suggest that this participant background played a role in the answers.

This participant also made observations on the functional side of the systems, as transcribed below.

P2: It would be interesting to have a rod to help identifying where the camera is on both systems, instead of having verbal instructions on how to locate it.

4.3.3. Both Equally Liked

P4: As they both did the same, I like either. However, the robot is more beautiful, and I would like to have it at home. The robot also becomes more interesting because, you know, the computer is very common and everyone has one, but not a robot.

P6: I like both, and I like that both seemed concerned with me.

P7: It made no difference due to the task, but I would prefer to interact with the robot on a daily basis. Robots seem easier to carry around.

P4 and P7 explicitly said they liked to interact with both systems because the task was the same and they had successfully completed the task, but that they would rather interact with JD.

Thus, if we consider that the task was deliberately intended to evoke the same feelings towards either system, the participants' answers support Hypothesis 1, where we say that *participants will prefer to interact with the robot*.

This is supported by research in the SAR area (see 2.2). [Matarić et al. 2007] compared participants interaction with a physical robot, a remote physical robot seen through a screen, and a virtual robot. Participants found the physically present robot to be the most watchful and enjoyable of the three conditions. In addition, they explain that unlike non-embodied technologies, robotics makes it possible for personality to be expressed not only through voice and appearance, but also through the use of proxemics (personal and social space), thus interfering on the user's preferences.

4.4. Discussion and Limitations

As an emerging field, socially assistive robotics has little published research to which we can compare our results, especially regarding blind users. In this section, we discuss our findings relative to the perception of users and observations made by them towards the embodiment and other aspects of the robot.

An important aspect of the interaction between humans and robots is the autonomy of the robots. In our experiment, we tried to make JD as autonomous as possible, but we did warn the participant about the beverage being ready. The complexity of this specific task was not the focus of this study, and it is left to be explored in a future work. As [Fong et al. 2003] said, it is essential to keep improving autonomous capacities, but we must not overlook enhancing the human-robot relationship.

At the end of each interview, after asking participants what system they preferred to interact with, we gave them the opportunity to talk about the interaction and the systems. The majority of observations were made towards JD, with little mention of the computer. Below we transcribe and comment the participants' observations.

P1: I find the robot nicer, but both seem competent and care about prevention, asking me to take care with the hot beverage.

In addition to participant P1, participants P4, P5 and P6 (as transcribed below) seemed thrilled about the systems warning them about the beverage being hot. This seems to be a key aspect for any socially assistive system, embodied or not. Since it deals with vulnerable users, they must be aware of the users needs, carefully considering their disabilities [Tapus et al. 2007].

However, a robotic system has advantages over non-embodied agents regarding safety. In our experiment, we executed the same procedure for both systems, not using the full capacity of our humanoid robot, as we wanted to investigate if the physical embodiment played a role in the social interaction. Nonetheless, in the context of our experiment, the robot could have been able to retrieve the cup and to give it to the user only after it was safe for them to hold it, as P3 point out. This kind of functionality would certainly increase the users likeability towards the robot.

P3: As the computer is something very common, I do not perceive it as a companion. The human aspects of the robot make the interaction better. It should be interesting for both systems to know when the cup can be removed [from the machine], and our responses to the robot should be very straightforward and not too predefined. It could be "I want coffee" or something like that at the beginning, instead of "let's start". But I really liked the sympathy of both systems as we talked.

In our experiment, we used a set of grammar definitions that would trigger predefined answers in order to make the system as autonomous as possible. This could be enhanced in future research, as P3 pointed out, and could potentially improve the users perception of the robot.

P4 also made an observation toward the speech capacity of the system, mentioning the fact that it would ask to repeat in case it did not understand what was said. The idea of having more naturalistic language has been extensively researched [Mavridis 2015, Kulyukin 2006]. Two participants said "thank you" at the end of the experiment with JD, during the first interaction. This word was not in the grammar, what made JD ask them to repeat. Both participants had a very similar behavior afterwards. They promptly repeated it and, as JD asked them to repeat it one more time, they laughed and did not say it again. No participants thanked the computer.

P4: I would love to take the robot to the market to identify the products and prices and to guide me. It would be very interesting for a robot to do so. I like that they [both systems] were concerned about the beverage being hot and that they asked me to repeat if they did not understand what I said.

P4 desire to have the help of a robot while shopping is a topic that has started to get attention from researchers. The ongoing studies on independent shopping (see 2.3) could potentially benefit from social interaction and embodied agents that resemble humans, as that could help the users feel more comfortable and get help in different ways.

As seen in 4.3.3, P4 said that JD was more "beautiful" than the computer. This participant has congenital blindness, so it seems that the fact that JD has a body had a strong influence on their opinion about it.

P5: I think the robot's voice seemed more "alive." Both were concerned about the drink being hot, that was nice of them.

P5 thought that the JD's voice was more "alive," even though both systems had exactly the same voice.

P6: It's a very interesting kind of technology. They even worried about the beverage being hot.

All participants had the opportunity to ask the system for instructions on how to operate the coffee machine, but only participants P4, P6 and P7 used this feature. We noticed that they only asked this to JD. Even P4, who had already interacted with the computer during the first week, asked the robot. Only P7 payed attention to the instructions. The other two started preparing the beverage and were done with it before the system asked if they needed further instructions. The experimenters noticed the participant's enjoyment while listening to the instructions, even though they did not seem to need it.

P7: For future robots, I would love to see them folding and separating my clothes, or even simply identifying the colors of clothes and other objects. They could also monitor me while I cook. That can be kind of dangerous, but I love to cook.

All of these observations are very important for the future of socially assistive robotics. They bring ideas of how social robots could be used in order to help the blind as well as address more generic topics that, although researched in areas such as human-computer interaction, should be considered for the development of the interaction between robots and blind people.

Our initial plan was to develop a long-term study. Due to lack of funding and logistic issues, we were able to do only a short-term study with two interactions over two weeks. Thus, long-term studies in the future could lead to a broader understanding of the relationship between social robots and blind people, as well as to diminish the novelty effect, as two participants commented about liking the robot because "not everyone has one." Furthermore, new research could evaluate ways of overcoming this issue.

However, while interacting with the robot, participants responded to it in ways that the novelty effect does not seem to play a role. For example, some participants thanked the

robot and did not thank the computer, suggesting their attachment to the robot represents some kind of relationship that did not occur with the computer. At this moment, the embodiment of the robot seems stronger than the presence of the computer. Additionally, comments about the way a robot could help them in the future demonstrate their will to have this embodied agent by their side while doing other tasks.

Nevertheless, in our short term experiment, participants seemed to like JD more than the computer, engaging and showing more interest on it, though long term studies are needed in order to test whether this feeling remains or decreases over time.

5. Conclusion

In this paper, we investigated the perception of blind people towards a socially assistive humanoid robot. We found evidence that the robot's embodiment might be linked to the users' preference for it. SAR works with the most different kinds of special needs, and this study was developed keeping in mind that blind people might enjoy a social robot as much as a sighted person. This research is intended to shed light on the topic, contributing to the a brand new research topic.

Touching the robot helped the blind to understand the robot's body. [Diderot 1916, p. 77] mentions a congenitally blind man thought about the way he perceives the world around him. The man said,

it seems to me that my hands would tell me more about what happens on the moon than you can find out with your eyes and your telescopes; and besides, eyes cease to see sooner than hands to touch.

Therefore, blind people use their hands to perceive the environment around them, sensing objects in their own personal way. The participants in our study were free to touch the robot as much as they wanted, what helped them to recognize the robot's embodiment.

Combining an appealing physical embodiment with social aspects in a robotic system designed for the blind may improve their lives in a variety of different ways. While the functional part of the robot can be used to help them with specific tasks, it may also improve their self-confidence (e.g., on doing tasks without having to ask other people), make them feel happier for having a companion and evoke other positive feelings, as well as motivating them to socialize more (e.g., talking about the robot with peers) or to exercise more.

The physical presence of JD clearly had an impact on the users perception of it, but whether that is part of the novelty effect should be addressed on long-term studies. Future work may also explore other functionalities for the robot as described by some participants, and ongoing research on wayfinding and independent shopping could pay more attention to the embodiment of their agents, as well as to use social interaction in order to enhance user experience.

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