DESIGN CULTURE(S)

Cumulus Conference Proceedings Roma 2021

Volume #2

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Cumulus Conference Proceedings Series
07/2021 Rome

Design Culture(s)
Cumulus Conference
Proceedings Roma 2021
Volume #2

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Concept for Cumulus
Conference Proceedings
Series was developed in
2018 by Jani Pulkka

Cumulus conference
Design Culture(s)
hosted by
Sapienza University of Rome, Italy
on June 8-11, 2021.
Conference website:
www.cumulusroma2020.org

Published by Cumulus
Cumulus the Global Association of
Art and Design Education and
Research. Aalto University, School
of Arts, Design and Architecture
PO BOX 31000, FI-00076 Aalto
www.cumulusassociation.org

ISBN 978-952-64-9004-5 (PDF)
ISSN 2490-046X
Cumulus Conference Proceedings
Series, N°7

Cumulus Conference
Proceedings Series

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DESIGN CULTURE(S)

Cumulus Conference Proceedings Roma 2021

Volume #2

Cumulus Conference
Proceedings Series

Cumulus the Global Association
of Art and Design Education and Research

Rome 2021

DE SIGN CULT URE(S)

ROMA 2021

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DESIGN CULTURE(S) | CUMULUS ROMA 2021
JUNE 08.09.10.11, SAPIENZA UNIVERSITY OF ROME

From the evaluation of acceptability to the design of an assistive robot for elderly

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Abstract | According to a study conducted by ARS Toscana in 2014 the old people in Tuscany were 916.640 and there will be an increase of 36% in 2050. The “non-self-sufficiency” of elderly is a condition which entails their need of assistance. Often such a condition leads them to move from their home to the nursing home, radically changing their habits and everyday life. Over the past few years, robotics has represented a potential solution to improve the quality of life. This paper describes the methodology used for CloudIA research project, which concerns the development of an assistive robot to support fragile and non-self-sufficient people. An *ad hoc* questionnaire was developed to evaluate the acceptability. The questionnaire was addressed to 75 people, aged between 30 and 99 years, living in five nursing homes. The results allowed to target the design of the new robot.

KEYWORDS | DESIGN FOR THE ELDERLY, HUMAN-ROBOT INTERACTION, ACCEPTABILITY, ERGONOMICS IN DESIGN, HUMAN-CENTRED DESIGN

1. Introduction

The aging of the population is a widely known phenomenon. Europe is facing unprecedented demographic changes due to the progressive aging of the population and low birth rates (WHO, 2002), producing a significant increase of the over-80s in the total European population, even if the highest variations they are registered in Mediterranean countries such as Italy and Spain (ARS Toscana, 2014).

According to the worldwide projections, by 2050 people over 65 will be more than the double compared to the children under five. Globally, by 2050, the number of people aged 65 and over will also exceed the number of teenagers and young people between the age of 15 and 24 (United Nations, 2019).

As a result, Europe is facing the challenge of offering high quality and affordable health care to all citizens. This challenge is very tough because of the increase of the medical care need for an aging society, the costs of treating chronic diseases together with the constant demand by citizens for ever better health care.

This trend, increasingly prevalent in Europe and in Italy, is significantly marked in the Tuscany region. In fact, according to a study conducted by ARS Toscana (ARS Toscana, 2014), by 2060 almost a third of Europeans will be over 65 and the demographic trends in Tuscany are even more pronounced. In 2014 the elderly in Tuscany were 916,640 and they will increase by 36% in 2050 and there will be an increase of 36% in 2050. A typical condition of the elderly in need of assistance is the "non-self-sufficiency", defined as a functional impairment in the basic activities of daily life (dressing, personal hygiene, movements at home or away from home and nutrition).

The aging process and its related dynamics results in significant changes in the market in terms of demand of products, services and environments for the quality of life, especially in the field of diagnostics and monitoring. Luckily, the emerging technologies have the potential to help the old people to maintain their independence. They can support the users in mobility both inside and outside home and in daily activities, promoting social relationships and improving the feeling of security and therefore delaying the physical and mental decline. This is confirmed both by the rapid development of smart technologies aimed at improving services in different sectors, and by their economic accessibility among the population.

One of these technologies is robotics. For example, the assistive robots represent a fast growing business, as well as one of the most attractive sectors in the field of medical technologies. They have the potential to maintain or restore the independence of older people in the near future (Ezer, Fisk ,& Rogers, 2009; Fisk, Rogers, Charness, Czaja, & Sharit, 2009; Jayawardena et al., 2010).

Bearing all this in mind, this paper describes the methodology used during the Design phase foreseen by the CloudIA research project, financed by the Tuscany Region, which entails the development of a robot to support fragile and non-self-sufficient people (elderly and disabled) in the nursing home (for the elderly and for the disabled) and at their own home. For that purpose, an *ad hoc* questionnaire was developed to evaluate the acceptability of four commercial robots: Pepper, Sophia, RP Vita and Paro. More specifically, the following factors were assessed: appearance, humanity, facial expressions and adaptability. The results that emerged enabled the authors of this article to direct the design of the new robot.

The questionnaire was administered to 75 users, aged between 30 and 99, hosted in the 5 cooperatives involved in the research program.

2. Approach to acceptability evaluation

Over the past few years, robotics has become a potential solution to improve the quality of life of the users and the services provided to them: robotics can improve mobility, communication possibilities, promoting social inclusion and increasing the sense of security, e.g. through systems for monitoring vital signs and daily life activities (Jayawardena et al., 2010).

The scientific literature (Forlizzi, DiSalvo, & Gemperle, 2004; Goodrich & Schultz, 2007; Information Resources Management Association, 2017) provides many examples of robots developed to meet the needs of the users: health monitoring, drug assumption support, physical assistance and mediation between users and assistive technologies. Assistive robots can be classified according to the need they satisfy, including:

- robots for socialization;
- information robots;
- security robots;
- health robots;
- leisure robots;
- robots for physical support.

However, these technologies are not used yet, due to factors such as stigma, (non) adaptability or social influences (Heerink, Krose, Evers, & Wielinga, 2009).

Robotics appear as groundbreaking but, in the coming years, it will have to find a place among human beings and humans, in turn, will have to accept this technology.

To avoid a human-robot incompatibility, it will be important to ensure the acceptability and the adoption of robots by people. On this basis, the researches in the Human-Robot Interaction (HRI) field aims at understanding, designing and evaluating robotic systems for use by or with humans (Goodrich & Schultz, 2007). The HRI therefore focuses on the two dimensions of interaction: the physical one, which is often referred to as teleoperation or supervisory control and the social one, referred to social, emotional and cognitive aspects.

One of the key elements of the HRI is acceptability, together with safety and usability requirements (Salvini, Laschi & Dario, 2010).

In robotics, the concept of acceptability has received considerable attention, especially in the field of biomedical devices, such as surgical robots and robotic prosthesis, but it is gaining relevance also in the field of assistive devices and companion or domestic robots (Dario, Guglielmelli, Genovese, & Toro, 1996; Salvini, Laschi & Dario, 2010; Welch, Lahiri, Warren & Sarkar, 2010)

Acceptability is usually described as the “demonstrable willingness within a user group to employ information technology for the task it is designed to support”. The goal of acceptability is to measure and identify key determinants of user acceptance or resistance (Dillon, 2001).

The term “acceptability” is "user-centered”: it is exclusively based on the study of the relationship between a product and its user (Salvini, Laschi & Dario, 2010).

Robotics therefore opens new challenges for the discipline of Design and consequently for designers. The contemporary society needs products that meet people’s needs through a human-centered design (HCD).

This brings the need to develop evaluation methodologies. In particular, in the field of robotics and screen agents several methods have been used, varying from applying heuristics or other usability type tests and classifying tests to measuring physical responses (Heerink, Krose, Evers, & Wielinga, 2009).

The approach and the methods of Human-Centered Design are one of the possible strategies for innovation in the European production system and also for the small and medium-sized enterprise system (EU Commission, 2013).

Designing the acceptability (Design for acceptability) consists in applying principles and methods during the early stages of robot design in order to minimize the risk of resistance or rejection by users. According to some authors, designing acceptability means understanding the factors that can influence the adoption of technologies (Dillon, 2001) and assessing the HRI through five main methods: interviews, self-assessments, behavioral measures, psychophysiology measures and metrics of task performance (Bethel & Murphy, 2010).

This paper shows the methodology used for the design of a new robot. The presented methodology provided for the active involvement of end users (elderly and disabled), during the first Discover phase (as proposed by the Design Council's Double Diamond). Users completed a questionnaire for the evaluation of acceptability: the questionnaire was focused on those morphological, both general and specific aspects, able to give rise to users’ likeability and influence their attitude toward the robot. The main focus of the questionnaire method was to define the guidelines for the development and design of the new robot.

Given the nature of the end users and their location on the whole regional territory, the questionnaire was found to be the most effective method among those present in the literature, because it allowed to receive quantitative data in a short time (Stanton, Young, & Harvey, 2014). Data were subsequently interpreted and used during the design phase of the new robot.

After a review of the scientific literature relating to the acceptability of robots, the questionnaire was developed, with a special focus on Mori's Uncanny Valley (Mori, 1970; Mori et al., 2012). According to Mori, there is a non-linear relationship between the likeability or familiarity and the humanoid aspect of a robot. The appearance of a robot, when it is too similar to a human being, could annoy and generate in the observer disturbing feelings such as anxiety or negative attitudes (Mori, 1970; Mori, MacDorman, & Kageki, 2012).

According to the study conducted by Dario et al., the appearance of an assistive robot should not necessarily be anthropomorphic. Consequently, the best design solution should be a balanced mix between the domestic device appearance and the machine appearance (Dario, Guglielmelli, & Laschi, 2001).

On the contrary, Breazeal claims that when designing a robot, it is essential to consider that humans, as an extremely social species, uses his socio-emotional intelligence to understand the behaviour of more complex entities, like people or other living things. Human beings interact with other non-living elements with sufficient complexity, applying social models to explain, understand and also predict their behaviours. For example, people are known to anthropomorphise all sorts of technology (e.g. cars, computers, etc.) (Breazeal, 2003).

The same author also argues that people generally apply a social model when they observe and interact with autonomous robots. Autonomous robots make decisions and perform actions independently to perform their tasks. This makes them, for human beings, similar to a creature with which they can communicate, cooperate and learn from: for this reason, it is almost impossible for anyone to not anthropomorphise them (that is, to attribute human or animal qualities to them).

As claimed by Breazeal, aesthetics is fundamental in a robot:

> "when designing robots that interact socially with people, the aesthetics of the robot should be carefully considered. The robot's physical appearance, its manner of movement, and its manner of expression convey personality traits to the person who interacts with it. This fundamentally influences the manner in which people engage with the robot" (Breazeal, 2005).

2.1 The questionnaire

As stated by some scientific evidences (Johnson, Slaughter, & Carey, 1998; Scheeff, Pinto, Rahardja, Snibbe, & Tow, 2002; Minato, Shimada, Ishiguro, & Itakura, 2004; Breazel, 2005), the morphological aspect of the robot can influence its interaction with the human beings. This is more evident in relation to specific groups of users such as the elderly. Therefore, in the period from May to October 2019, an online questionnaire was sent to the 5 cooperatives partner of the CloudIA research program.

The specific objective of the questionnaire was to understand how the end users perceive the four selected commercial robots, and which aesthetic features they accept and find more likeable and acceptable. The four commercial robots were chosen after a careful review of the scientific literature as well as for their functionality and services provided.

As a result, the following robots were selected (see Figure 1):

- Pepper (Android), produced by the Softbank Robotics company. The robot is able to talk, understand, move independently, and react to emotions;
- Sophia (Humanoid), produced by Hanson Robotics. It is a platform created for advanced robotics, for AI research and for exploring the Human-Robot Interaction;
- RP Vita (Automaton), produced by AB Medica. The robot provides the remote presence service within hospital and care-intensive environments;
- Paro (Zoomorphic), produced by Paro Robots. The robot was designed to provide therapeutic assistance to various kinds of patients. It can be used both in the hospital and at home.

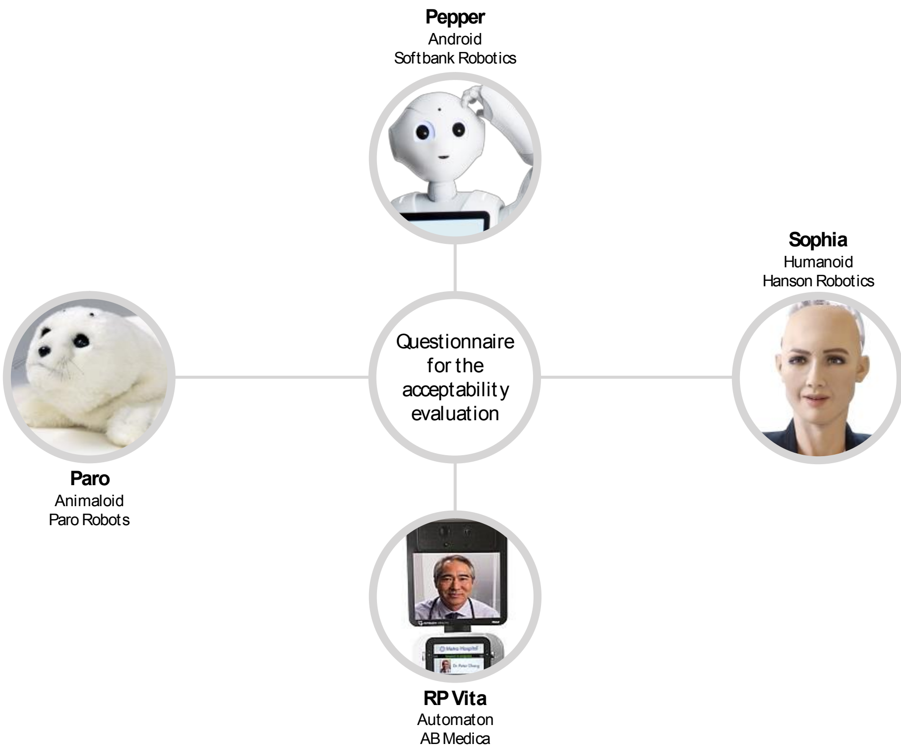

Figure 1. The four selected robots for the questionnaire.

The questionnaire was submitted to two categories of users (elderly and disabled), aged between 30 and 99, all hosted in the cooperatives partner of the research. 75 users of both genders participated in the questionnaire.
The questionnaire consists in 4 yes-or-no questions and 1 open-ended question:

1. is this robot beautiful? Y/N
2. is this robot likeable? Y/N
3. would you stay alone with it? Y/N
4. would you hug it? Y/N
5. is there anything in particular that you like?

3. Results

The data collected from the acceptability questionnaire are shown below.

17 males and 58 females replied to the questionnaire. 12 of them were under 65 (<65) while the other 63 were over 65 (> 65). Table 1 shows in detail the age of the users who took part in the survey (see Table 1).

As for the first question "is this robot beautiful?", most of the participants showed pleasantness towards the robots Pepper, Sophia and Paro. While for the RP Vita robot only 49% said that the robot is beautiful (see figure 2).

As for the question "is this robot likeable?", the data relating to the 4 robots are very similar (see figure 2).

Different results emerged from the question "Would you stay alone with it?". As shown in figure 2/question 3, the 49% of the interviewees would stay alone with the Pepper robot. While the 51% would stay alone with the Sophia robot. As for the RP Vita robot, only the 41% would stay alone with the robot and the 60% of the interviewees would stay alone with the Paro robot.

The results from the question "would you hug it?" are very different. The 65% of users would not hug the Pepper robot. The 56% would not hug the Sophia robot, and the 80% of interviewees would not hug the RP Vita robot. The 56% of interviewees said they wanted to hug the Paro robot (see figure 2).

Age	Participants	Gender	Age	Participants	Gender
30	1	Male	83	2	Female (2)
42	3	Female (3)	84	5	Female (5)
53	1	Male	85	6	Male (1) Female (5)
58	2	Male (2)	86	3	Male (1) Female (2)
59	1	Female	87	2	Female (2)
61	2	Male (1) Female (1)	88	2	Female (2)
62	1	Female	89	3	Male (1) Female (2)
63	1	Female	90	4	Male (1) Female (3)
65	1	Male	91	3	Female (3)
68	1	Male	92	3	Male (1) Female (2)
73	1	Male	93	2	Female (2)
75	1	Female	94	2	Female (1) Male (1)

77	1	Female	95	4	Female (4)
78	1	Female	96	3	Female (3)
79	2	Female (2)	97	1	Female
80	4	Male (3) Female (1)	99	3	Female (3)
81	3	Female (3)			

Table 1. The age of the users who took part in the survey.

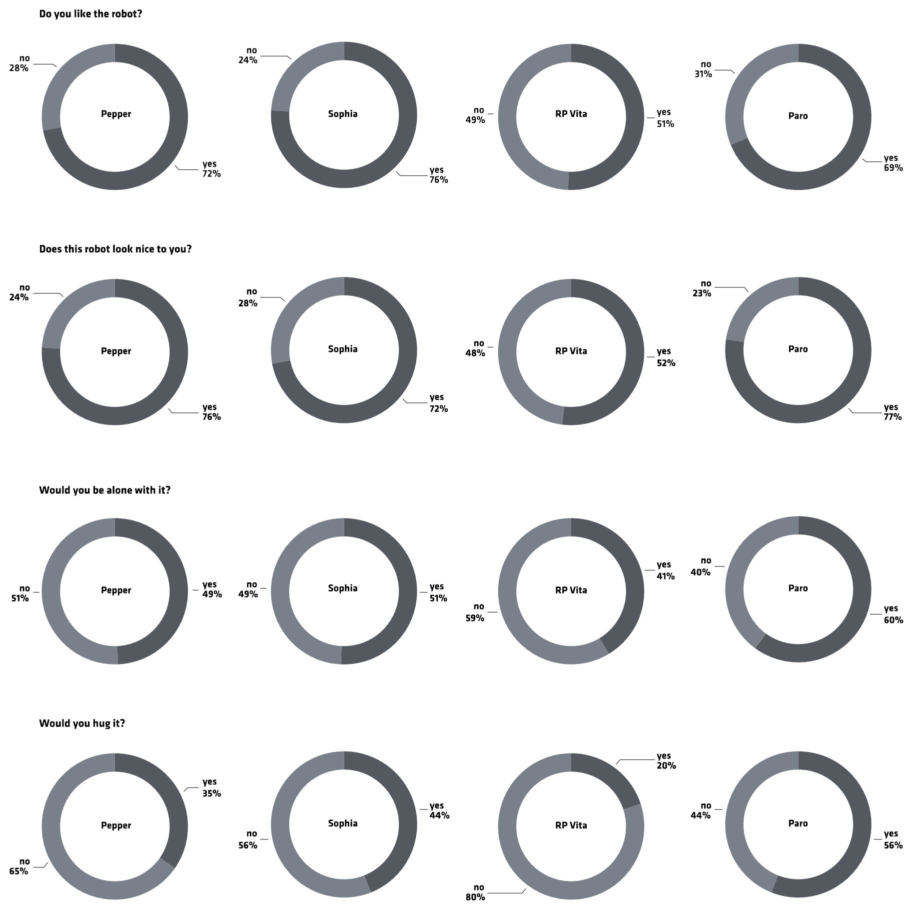

Figure 2. The data emerged from the questionnaire.

The results that emerged from the question "is there anything in particular that you like?" are very interesting.

As shown in figure 3, although many of the interviewees stated that there is nothing particularly beautiful in these robots, the data suggest a high degree of pleasantness towards the following characteristics of the selected robots:

- face;
- eyes;
- mouth;
- hands;
- arms.

In conclusion, the results show a strong tendency to appreciate soft and smooth shapes, with non-humanoid features.

Furthermore, the display is not considered as an annoying feature of the analysed robots.

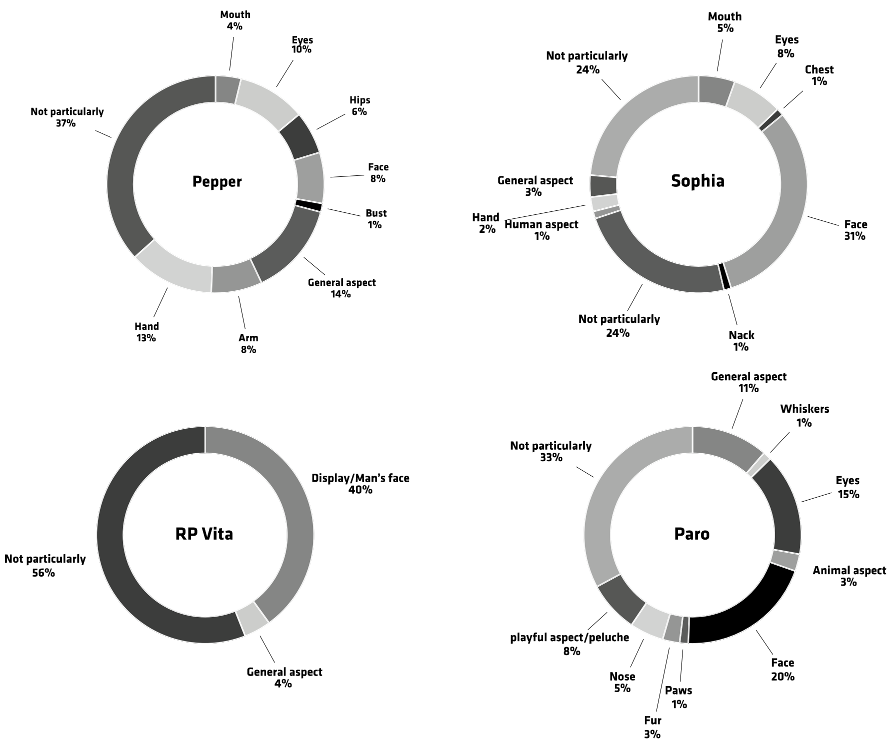

Figure 3. The results from the question: "is there anything in particular that do you like?"

4.1 The new robot: CloudIA

Before proceeding to the design of the new robot (sketch, 2d and 3d drawings and renders), simultaneously with the submission of the questionnaire, together with the cooperatives involved in the research program, the *desiderata* were defined: they were useful for defining the new robot features in relation to the real needs and expectations both of the end users and of the health care workers who provide daily service in the nursing home for the users and also at home.

The *desiderata* allowed to design a new robot for assistance, socialization, active support for hydration and for the assessment of users' cognitive and/or physical abilities, to be used both in nursing home and at home (Pistolesi & Becchimanzi, 2019).

After the definition of the design brief, the design and development of the robot was conducted on the basis of the user analysis. Specifically, the development of the robot was carried out on the basis of the results that emerged from the desiderata and the acceptability questionnaire. Moreover, the new robot was designed also in relation to the robotic platform designed and assembled by the Institute of BioRobotics of the Scuola Superiore Sant'Anna in Pisa, a research partner together with the authors of the CloudIA research program (see figure 4).

Although the robotic platform has constrained the shape of the new robot, its final shape is smooth and balanced, without protruding elements or edges. The chassis of the robot is made by three elements: a right part, a left part and a compact hinged door with magnetic closing. The basis is larger than the top so as to ensure the stability of the entire robot. The chassis topcoat are smooth and soft. In order to satisfy sustainable aspects, the entire body of the robot is made by plastic urban wasted 3d printed.

Furthermore, it was necessary to design a mobile arm to orient and support the tablet. It is fixed to the highest part of the robot chassis in order to allow the user to arrange and interact with the display. This feature provides a greater humanization of the robotic platform.

The height of the new robot, and consequently the customizable position of the tablet, allows all users to interact with the tablet without excessive effort.

The tablet is useful to carry out the following activities:

- hydration support through an alert;
- support to drugs intake through an alert;
- socialization activities in common areas;
- emotional/cognitive status monitoring through the submission of the Mini-Mental State test (Folstein, Folstein, & McHugh, 1975), currently used by the 5 cooperatives;
- cognitive stimulation.

These activities will be tested within the 5 cooperatives involved in the research program.

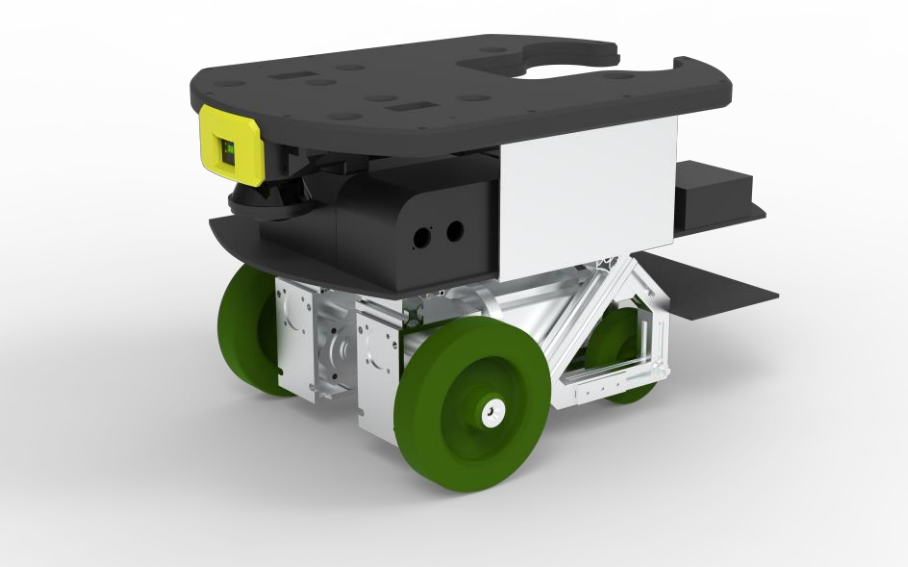

Figure 4. The robotic platform assembled by SSSA.

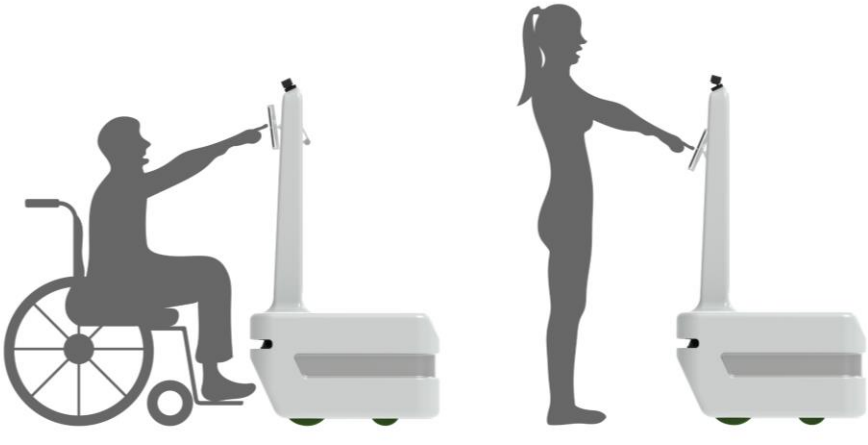

Figure 5. The new robot.

Figure 6. The new robot.

5. Conclusion

This paper presents an experimental methodology, aimed at applying the Human-Centred approach to the design of assistive robotic technologies. In fact, as stated by Forlizzi et al. (Forlizzi, DiSalvo, & Gemperle, 2004), many of the products analysed by the scientific literature on assistive robotics, have been designed with little consideration of the social, aesthetic and emotional relationships that the users will establish with the product.

The HCD (Human-Centred Design) approach, applied by the authors of this article, focuses on the analysis of users' needs, aspirations and expectations declared and/or tacit, so that they provide the basis for the design of the new robot.

The experimentation and design development presented in this paper are based not only on functionality and efficiency but also include elements such as attractiveness, likeability and the absence of stigma and non-reluctance towards technology.

The research methodology was aimed at obtaining feedback on the various personal aspects that contribute to generating the complex human-product interaction. Although this is influenced by extremely subjective factors and the personal experience of each individual user, it can be designed according to universally shared patterns and features.

The collected data contributed to the development of an accurate knowledge of the profiles of pilot users who will subsequently interact with the robot.

In addition, although the Design is often associated only with the aesthetics of products, its application is actually much wider. The Human-Centred approach therefore becomes a fundamental requirement in order to create a truly suitable, useful and acceptable product.

In conclusion, the next step of the research program concerns the definition of a new experimental protocol aimed at evaluating the overall experience of Human-Robot Interaction, through the analysis of the emotional quality of the interaction, such as acceptance, safety, intentions, perceived likeability. The experimentation will be conducted with pilot users both at home and in the nursing home for the users.

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Acknowledgements: The authors would like to thank the guests and the social-health workers of the social cooperatives of Tuscany for their participation and for their valuable contribution to the exploratory survey. In no particular order: Arca cooperativa sociale, Uscita di Sicurezza, C.RE.A cooperativa sociale, Pane e Rose and Gli Altri cooperativa sociale. Special thanks are due to Dr. Filippo Cavallo, to Dr. Laura Fiorini and to Ivan D'urso of the Institute of BioRobotics of the Sant'Anna School of Advanced Studies in Pisa, and finally to Jacopo Francesco Montalto for his fundamental contribution for the development and design of the new robot.