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Proceedings of the 8th International Forum of Design as a Process

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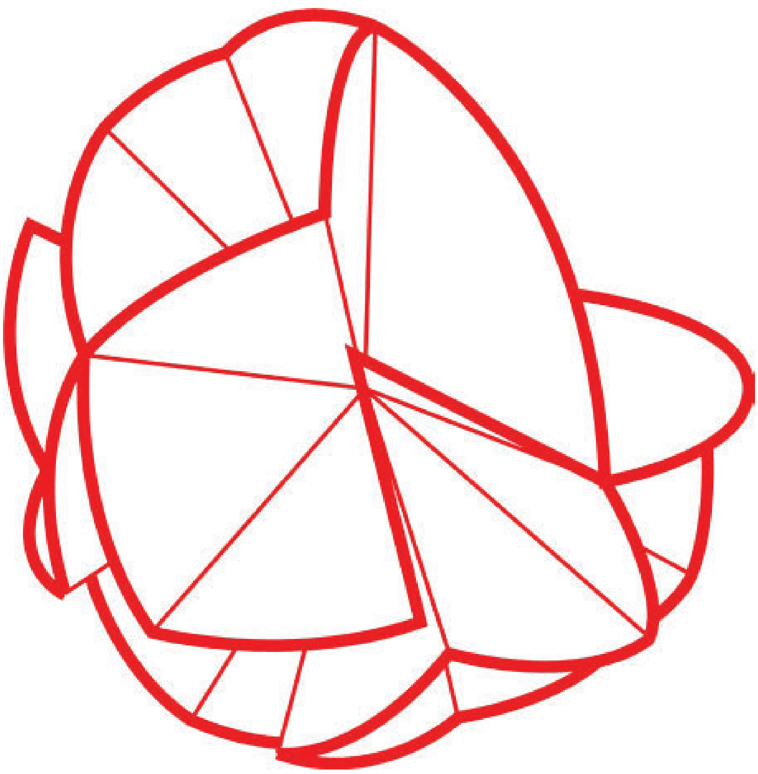

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diid
disegno industriale
industrial design
Digital Special Issue 1
— DSI 1

Year
XXI

diid is an open access
peer-reviewed scientific
design journal

diid is published
three times a year

Registration at Tribunale
di Roma 86/2002
(March 6, 2002)

www.diid.it

Print subscription
(3 issues)
Euro 60,00
Subscription office
ordini@buponline.it

Publisher
Fondazione
Bologna University Press
Via Saragozza 10
40123 Bologna
Tel. (+39) 051 232 882
Fax (+39) 051 221 019
www.buponline.com
info@buponline.com

ISSN
1594-8528

ISSN Online
2785-2245

DOI
10.30682/diiddsi23

ISBN Online
979-12-5477-329-1

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The Editors extend their sincere appreciation to the following Scholars who served as Reviewers for this Digital Special Issue.

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Are You Me? Re-Embodiment Process for Telepresence Robots

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Abstract
Accessibility in distance education activities represents a challenge that needs to be addressed with a view to social inclusion and collaboration between the stakeholders of the school system. Also, as a resilient response to the Covid-19 pandemic, today we are witnessing research and experimentation on the theme of connecting people at a distance through solutions and tools designed to facilitate the teaching/learning process and socialisation, to make the impact more human with advanced digital technologies for image transfer.

In this direction, telepresence robotics demonstrates a discrete potential regarding pedagogical effectiveness and social inclusion. Still, it also needs to investigate in greater detail the requirements for acceptance and service management.

This contribution presents the results of a workshop/laboratory with university students at the Politecnico di Torino to investigate the first requirements related to the physical and cognitive embodiment of the telepresence robot through an interdisciplinary co-designing experience.

Keywords
Social robot
Telepresence robot
Human-robot interaction
Robot embodiment design

Introduction

The development of research and experimentation in social robotics has led the discipline of Human-Robot Interaction to question the acceptability of and trust in such machines from a semantic and functional perspective (Jost et al., 2020). The aim is to design increasingly high-performance scenarios for a machine that can appropriately perform specific tasks about the user and context of the application. In the interaction between the person and the robot, embodiment, i.e., the combination of the physical body, gestures, and speech, plays a key role in the robot's interface with the outside world, primarily with and between people (Falcone, 2020). Therefore, the embodiment is regarded as a transitional element between the virtual algorithm underlying the machine's operation and the natural communication of forms and expressions. It is the result of a complex mediation between functions, meanings and expressions that have been studied for years by interdisciplinary expertise: the hard (mechatronic and computer engineering), the soft (cognitive psychology and neuroscience) and the design (design). Design makes available to this research its holistic and problematic approach to design and its methodologies of experimentation in co-design with users. These concern the evaluation of the formal/expressive solutions of the machine and the languages for interaction and the final evaluation of the user experience (Ostrowski et al., 2020).

In the relationship of trust between the person and the machine, the possible characterisation of the embodiment and interaction plays a key role, which can take place by user groups or even as customisation on a single user (Pinney et al., 2022).

User satisfaction depends, in some cases, e.g., for children and adolescents, on the physical adaptability of the machine. At the same time, the interaction's easy, familiar, and social (even fun) accessibility remains a universal goal. This affects the robot's ability to respond quickly and articulately through movements, gestures, lighting, and sound feedback.

Today, however, there are still no telepresence robots that can be characterised in the body: the desire for embodiment customisation clashes with the difficulty of building machines with high adaptability. Indeed, research into machine characterisation places severe engineering constraints on physical transformation in terms of transportable weight, speed of movement and battery autonomy. However, this remains one of the most ambitious goals. In contrast, the different configuration of digital interfaces, a performance already integrated into some series and prototype models, allows incremental adaptations of the robot's levels of expressiveness and communication. This paper aims to develop a co-design methodology for implementing the social and expressive empathy inherent in the interaction with a telepresence robot to be included in the university context, but also to facilitate the life of the remote student by improving his learning and sociability. This objective was the starting point for an initial robotics interaction workshop in which design students, assisted by psychologist mediators and mechatronic engineers established an experimental relationship with the machine, playing the alternating roles of interaction designer and evaluator and user.

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Doi: 10.30682/diiddsi23t3b

Background

Telepresence robots are tools that allow subjects unable to be physically present to be remotely connected not only with audio and video but also through a body capable of moving in space and following activities behaving as an avatar of the distant subject (Kristoffersson et al., 2013). However, such applications still show many limitations precisely because the tool cannot contextualise and characterise itself concerning the context of use and the different types and ages of users (Tsui et al., 2015).

There is still room for research into a robotic machine whose profile of the subject can characterise physical and digital interface at a distance, and which can interact more with the person or group in the physical presence (Fitter et al., 2021). This refers to a complex machine in which the body (head, torso and limbs) and sensory communication (looks, gestures and voice) make the interaction more accessible and identifiable.

The study of cognitive and physical embodiment as a mediator of communication between people at a distance involves exploring activities that occur in two distant but interacting contexts (Nosengo, 2013). Telepresence is an eco-system in which users, environments and devices located in distinct places and with different levels of interaction take part.

Remotely, the user guides the robot through 'input' devices such as a computer, tablet/smartphone and headset. The robot here acts as a subordinate, executing commands in space and interacting with users in their presence. Nevertheless, here its role changes, establishing a communication relationship based on the interaction between 'outputs' consisting of the physical body, audio, video, sound, and light (Björnfot, 2021).

Considering the current limited performance of telepresence robots, in the first case (piloting), it is the digital interface that is the main object of design activities, as it provides the user with situational awareness and awareness of the space in which the robot moves (map-based or video-based control). The freedom of interaction is limited to movement alone, without the possibility of the user having other elements to represent himself, his emotions and gestures. However, even in the second case, i.e., the environment in which the robot and the user(s) are present, apart from audio-video communication, today, these subjects have no other possibilities of interaction with the machine.

These differences in roles and interactions depend very much on the 'context' and the 'type of user'.

Let us think about the physical appearance, i.e., the robot's body. Telepresence in the context of elderly care, e.g., compared to the school context, describes different uses and roles of both the robot and the users. The older adult does not drive the robot remotely but receives assistance and comfort via a screen integrated into the machine. Different people such as family members, friends and doctors take turns appearing with their faces or figures on the screen of a robot whose body does not represent them, not least because it would be challenging to change identity abruptly with the technologies we have today. Whereas in the case of the distance learner, as the robot's body physically complements a single person's face at a distance, this could take on a more specific physical and sensory communication identity (Isabet et al., 2021).

For the older adult, the robot's physicality and embodiment are still essential, but they carry other meanings. For example, the older adult asks the robot for a reassuring identity and comfortable gestures through physical contact and voice, combined with an attentive and quick presence in performing commands. In contrast, in the case of the remote student, being part of the group is the absolute satisfaction associated with effective tele-movement performance in space and interaction.

Again, we have different roles of the machine in relation to the context and the different types of users. In the case of the school environment, they are considering the different age groups of the student (primary school, secondary school, university), and the emotional manifestations and behaviours of the user(s) change. In other words, different empathy relationships with the machine are triggered by a mixture of biological and cultural factors; consequently, the performance required to ensure a comfortable and engaging experience varies (Casoni & Celaschi, 2020).

Therefore, designing socially and culturally effective interfaces still presents many questions and difficulties, mainly due to many context and user-type alternatives that may vary according to factors such as age, gender, culture, and digital abilities. Moreover, to which are added the personal behaviours and reactions of the person determined by the degree of trust, acceptance, and familiarity in interacting with a robot.

These design problems, which are difficult to approach, are today referred to in the robotics interaction literature as 'wicked problems, which are influenced by multiple factors and are therefore indeterminate: this means that there are no established solutions to them, whereas there may be more than one appropriate solution for each problem (Luria et al., 2021). Precisely because these are problems of an unstructured nature, the contribution of empirical and experimental research is crucial for defining guidelines to support design.

We are witnessing, on the part of various research institutes located in various parts of the world (around 40 of those mapped by the UXDPoliTO research group), a proliferation of solutions in which telepresence robotics is introduced into education in spot experiments linked only to the pedagogical effectiveness of the tool and ease of use. This brings to light the lack of research in terms of possible characterisations and customisations of the robotic machine consistent with the 'context' and the 'type of user' carrying out different activities: what well represents a future of development of social service robotics marked by the enrichment of performance in terms of technological humanisation and flexibility of use [fig. 01].

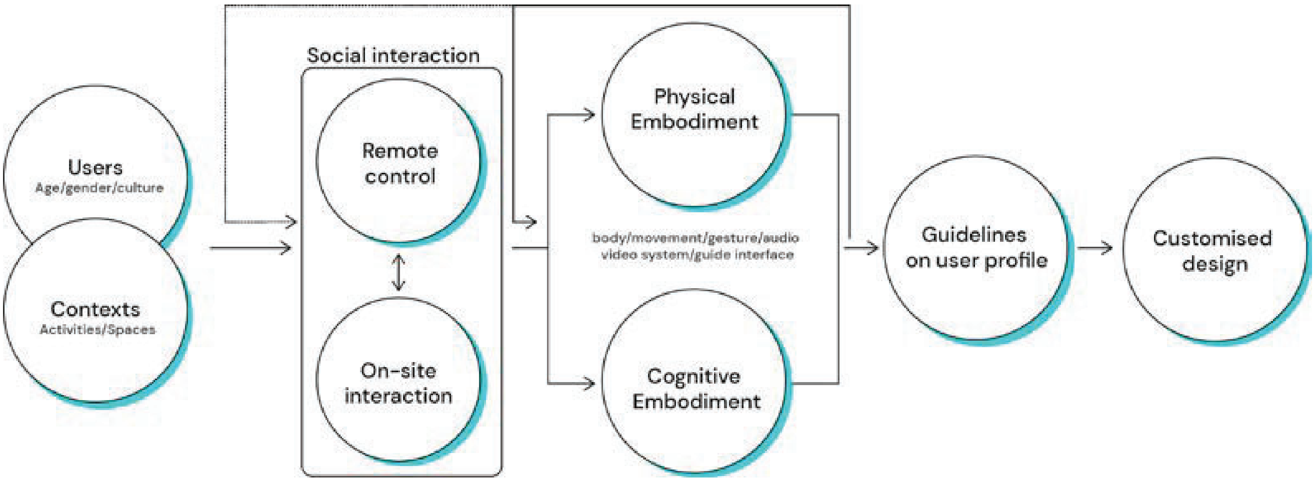

Fig. 1
Design process for characterising social telepresence robots for a given context/user. Credits: authors.

Co-Design Robotics Workshop

Increasing the effectiveness of social robots as mediators between people has become an urgent goal for both research and the market. The importance that grows exponentially with the spread of robots in many areas of daily life is directly linked to confidence in the usefulness of these new technologies. Among the main obstacles are the problematic, indeed cumbersome, operation of the robot, which does not allow an intuitive guide like what happens with other devices, and the slowness of the offer, especially of the machines that are now on the market, of incremental performances in terms of customization and ease of management and maintenance, as well as a still elite cost. A work aimed at increasing the acceptance of the machine by improving performance both from the social and managerial level, allowing the remote student to improve their academic performance and social life. By decreasing the load of actions that the individual has to carry out remotely, he will be able to concentrate more on educational activities and on life with his classmates, supported by their actions.

Motivations that direct robotic research, also through the contribution of design, to involve users in the design process right from the start (Bartneck & Forlizzi, 2004). As far as design-driven methodologies are concerned, there are at least three moments in which the evaluation of the process with users is essential: in the initial collection of considerations on the usefulness and relevance of telepresence robotics in facilitating and improving relationships between people (brainstorming); in the multi-criteria comparative evaluation of the accessibility and orientation performance of some models of serial production of robotic machines (benchmarking); in evaluating usability concepts and improving embodiment (prototyping).

The simulation of these three phases was the subject of the 'RoboPoli' workshop conducted in co-design between graduate students in Systems and tutors of the three disciplines (cognitive psychology, mechatronic engineering and design). The objective of the experimentation was the possible characterization of a telepresence robot in the university environment, starting from the analysis of the market trend and from the experimentation of a serial robot model accredited by our previous research. In the field of HCD, there are several research approaches used by researchers and practitioners in HRI projects: participatory design, ethnography, lead user approach, contextual design, co-design, and empathic design (Steen, 2011).

Co-design and participatory design are two of the methods in HRI that serve to address evil problems by placing stakeholders at the center of the design space while creating implementations or new technologies (Ostrowski et al., 2020). This approach to design allows for the identification of opportunities for technologies and the framing and reformulation of the problem space, creating artifacts as the iterative process of development, invention, evaluation of relevance and effectiveness unfolds.

In this context, it has been shown how participatory methods facilitate, on the one hand, the development of existing robotic applications and platforms and, on the other hand, the emergence of new common platforms and a greater sensitivity towards a greater contextualization of these machines (Björling et al., 2020).

HRH exploration by design

The workshop's main objective was to understand how the telepresence robot can better interpret the role of mediator between people in the concept of HRH human-robot-human. This fundamental characteristic distinguishes this category of machines. This was followed by experimenting with embodiment upgrade solutions to ensure that the robot's appearance and communication are consistent with the cognitive and interactive capabilities of the people using it and that the machine knows how to interpret the tasks to be performed in the context in which it operates (university environment).

Therefore, the co-design process within the workshop was based on participatory and human-centred design through steps of increasing inclusive level **Tab. I**.

The objective of the first exploration phase (scenario) was the description of interactions with distant subjects using telepresence robots. Limits and opportunities in using the machine by in-presence and distant students and teachers were collected as observation feedback. The areas of investigation were used as a basis for structuring the explorations within the co-design process.

The robot used to evaluate the implementations was the Double Robot model, an archetypal and synthesising product of all formal and functional characteristics found in telepresence robots.

The second phase of the work (concept) was concerned with implementations or adaptations of the chosen machine in favour of the university environment and spaces, evaluating its limitations and opportunities.

The students focused on specific activities, such as working in groups, sharing recreational moments in the spaces, and implementing and humanising the machine's communication system. The choice of group work derives from the fact that the students involved, within their university activities, carry out most of their work in groups and for this reason they have identified this activity as fundamental to consider.

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In the third phase (prototyping), the workshop developed re-embodiment concepts (Reig et al., 2019) of the chosen machine model and their evaluation. Re-embodiment refers to the contribution of artificial intelligence to characterising the person at a distance through the robot's body and gestures. Different levels of personalisation were experimented with in the course of the work, evaluating the social and interactive involvement in relation to the activities that characterise the university day. Several times the question "how could telepresence robots be turned into social robots for the university?" was posed to understand better the factors contributing to a greater social acceptance of telepresence robots in the school environment by putting the students themselves in the driving seat and receiving the reactions.

In designing the implementation of the machine, a design process with divergent and convergent phases was adopted, balancing concrete and abstract thinking. In the context of conceptual design, divergent phases allow more ideas and concepts to be generated, while convergent phases allow ideas and concepts to be narrowed down. The divergent and convergent activities within the co-design process were used to explore "open themes in an unconstrained manner" and subsequently "focus on more specific design objectives".

AREA	DESCRIPTION
Appearance	Evaluation of the general appearance of the physical interface of telepresence robots
Context of use	Assessment of the suitability of the robotics service for the potential application context
Interaction	Assessment of the level of interaction from both locations and potential future development scenarios

Tab. I
Investigation areas of the workshop.

Factors shaping HRH

In the initial stages of observing and evaluating the machine with the students, limitations and requirements were identified to implement the robot. During the brainstorming, the students questioned themselves on three topical moments of university life: classroom lectures, laboratory activities and library activities. In each of these moments, the point of view of the different actors involved in the telepresence ecosystem was used: peers at home, students in the presence and lecturers. In each of these specific situations, critical points in the interaction with the robots were identified through the construction of user journey maps. These included the lack of language and social interactions to improve communication Fig. 2.

The students then began to reflect on how they could perform daily tasks within the university, leading them to formulate two low-fidelity concepts and prototypes to implement telepresence robots: the first "Attracting attention without attracting attention" and the second "Immediate human interaction". The design of these scenarios helped to get the complete picture and plan the most appropriate interaction modes.

Each of the two prototypes underwent evaluation procedures. First, the designers tested their low-fidelity prototypes through the Wizard of Oz technique, when the robot is controlled or animated remotely but behaves as if it were autonomous. A quick and agile procedure to understand how implementations improved the relationship with the machine.

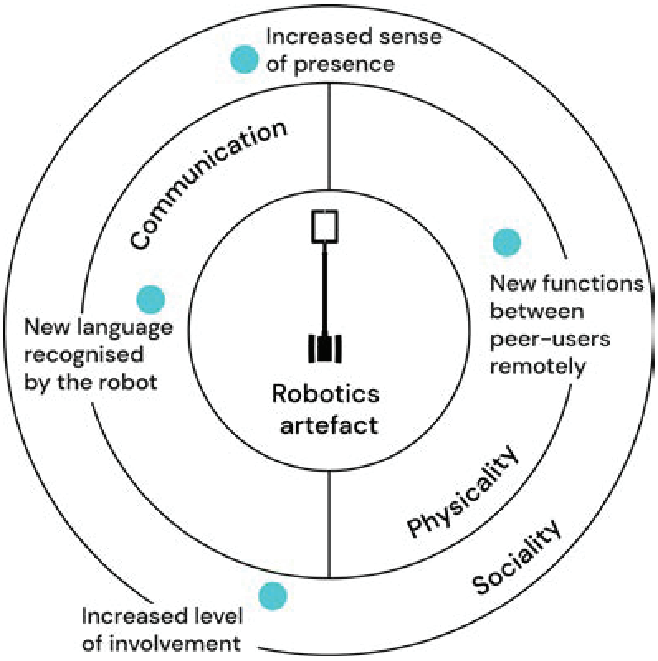

Fig. 2
Design intervention opportunities to implement telepresence robotics. Credits:authors.

Attracting attention without attracting attention

The first concept sought to increase the identity and self-presence of the person within the school environment, through humanised machine feedback, without making them invasive elements. The idea was to reintroduce human characteristics to increase empathy between peers, albeit distant, during the lesson to draw the teacher's and peers' attention or to express their intentions and emotions.

After analysing the application scenario, the students began with their concepts' modelling and prototyping phase. The students adopted the following as design solutions: the addition of a second screen integrated into the robot's stem for personalisation and non-verbal communication, a light element that simulates the raising of hands and attracts the teacher's attention during the lesson, and finally, an external wearable device that enables the follow-me function, which is not yet present in current robots on the market Fig. 3.

This solution aimed to increase the user's possibilities of expression remotely by including means for non-verbal communication and introducing gestures to make transmitting the message via telepresence more effective. For example, with the introduction of the flash, an attempt has been made to introduce an element that is not too invasive and is easily visible by the teacher even from a distance. While the second screen was useful for close communication with peers, adding a degree of playfulness and entertainment to engage participants.

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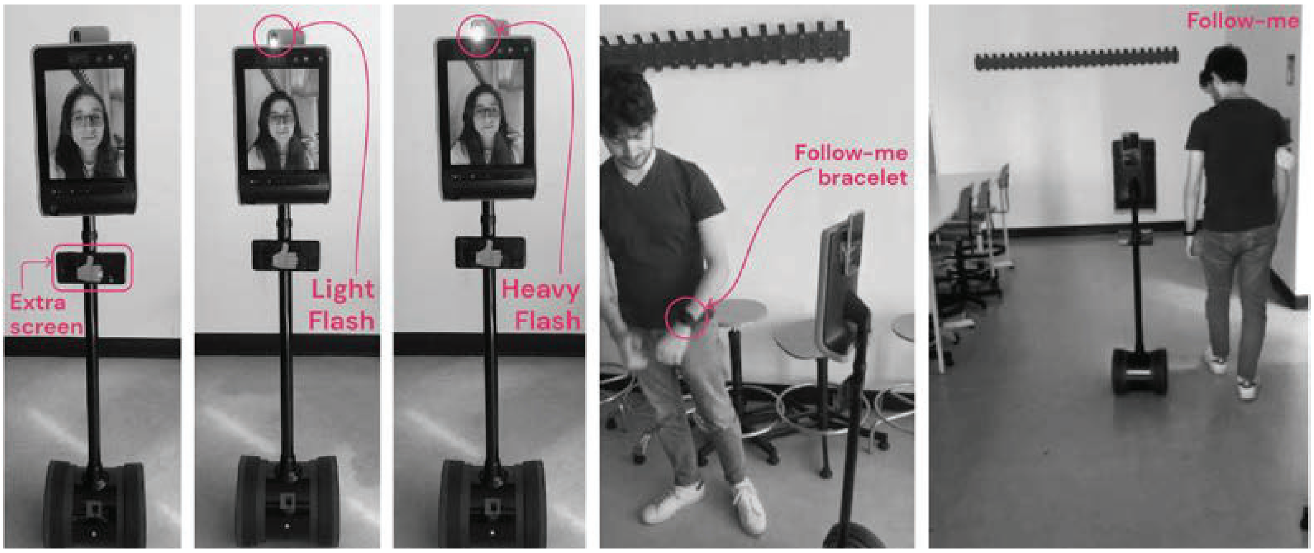


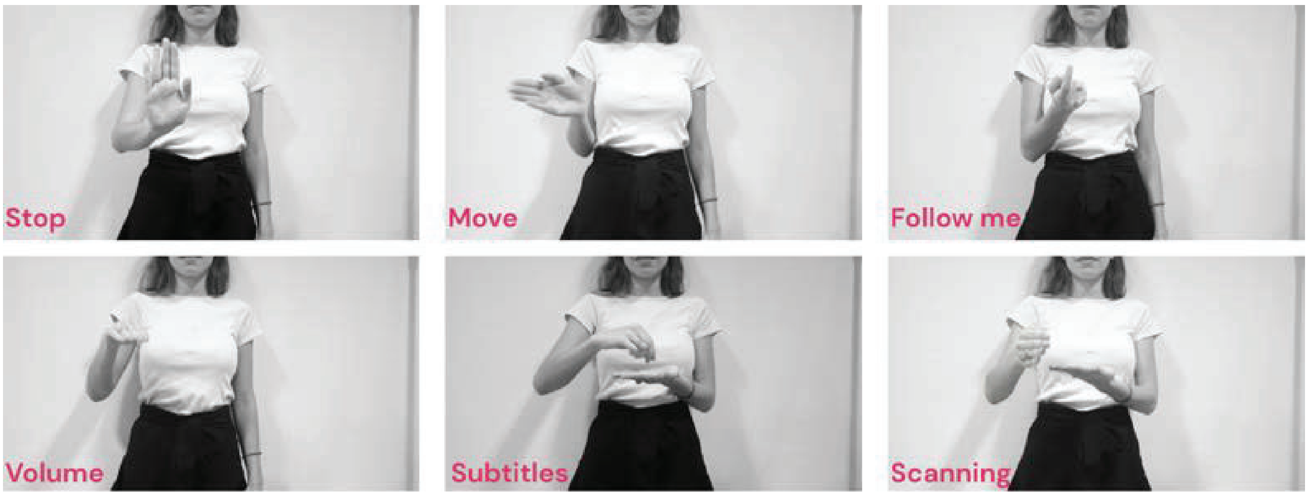
Fig. 3
Robot implementation with signal and follow me function. Credits: Abbate Lorenza, Germak Claudio.

Human and instant interaction

The second concept was aimed at defining actions to make the interaction with the robot during group work more human by codifying recognisable human movements Fig. 4. This work aimed to increase the level of interaction and guidance by the users in their presence.

In this case, the students worked on a tracking system to recognise the non-verbal gestures of the subjects in their presence to interact with the machine and make it perform specific actions. Each gesture was encoded and transformed into action by the robot. A system capable of allowing the subject in the presence close to the robot to have more significant interaction and control of the machine. The student at home will then have feedback on the interface of the control device on the changes made by the machine in its presence. However, the system is not only limited to gesture recognition but also voice recognition of the subject (e.g., calling the robot by the subject's name from a distance) or recognising where sounds come from. This is because when working in groups where everyone is placed at a short distance from the robot, the robot can understand the direction of the voice call so that it is directed in favour of the person it is interacting with.

Fig. 4
Research on non-verbal gestures for commands to be transmitted to the robot. Credits: Abbate Lorenza, Germak Claudio.



Reflections on co-design experience

This contribution provides a framework for the design and flexibility of embodiment related to telepresence robots. A scenario highlighted potentials and limitations in characterisation through bodily, gestural, and vocal communication, which varies as the context/user changes. A work brought to light the need for social norms between people and telepresence robots, defining a series of reciprocal interactions made up of impulses and responses. This is because social norms assume that much of people's behaviour is influenced by how other social group members behave. Nevertheless, also because human preferences for anthropocentric interactions are often presented as the reason behind the humanisation of robots, i.e., that if people effortlessly apply the rules of human-human interaction to interactions with non-human beings and objects, then the humanisation of robots will result in more natural and efficient HRIs (Duffy, 2006).

The experience also suggests moving away from the current convention of a passive and static robotic body, looking at the contribution of new technologies, e.g., in terms of dimensional and social variation of intelligent components. It will be helpful to think about the potential offered by combining several technologies and approaches to the subject of machine characterisation between the physicality of the machine and the digital image **Tab. II**.

All these solutions will result from hybridisations between the analogue and the digital until we can use holographic robotic machines, in which our virtual holographic representation, in scale and in real-time, will be able to ride around on wheels.

USER CONDITION	ROBOT REQUIREMENTS	DESCRIPTION
Remote	Personal Characterization	Extension of the image of the user inhabiting the robot, providing physical and digital interface upgrades of adaptability to the environment
On-Site	Social Characterization	Social interaction of the robot with the place and subjects are physically present through behaviours that abstract human-human interaction

Tab. II
Types of action based on the condition of the user and the requirements of the robotic system.

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