xCoAx 2024
12th Conference on Computation, Communication, Aesthetics & X
Fabrica, Treviso, Italy
2024.xCoAx.org

My Robot Body: A Workshop to Promote Body Awareness and Digital Literacy through Embodiment with Robots

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We present *My Robot Body*, a workshop exploring the relationship between human bodies and non-anthropomorphic robots to foster personal body awareness and interpersonal communication. Drawing from embodied cognition and theatrical techniques, the workshop integrates advanced technology with dance and theatre methods. Using wearable control devices, participants animate five non-humanoid robots featuring different expressive characteristics, integrated in a system that allows for flexible reconfiguration at runtime to promote experimentation and creativity. The workshop aims to transcend social barriers through body-based interaction and foster digital literacy by providing hands-on experience with robotics technology. Participants reported increased body awareness and a shift in perspective on technology. Despite challenges such as disconnection between controller actions and robot movements, the workshop received high satisfaction and was viewed as an effective learning tool. Led by a multidisciplinary team, *My Robot Body* highlights the potential of stage performance for human-robot interaction research.

1. Introduction

Research on embodied cognition and the Proteus effect (Banakou, Groten and Slater 2013; Kilteni, Bergstrom, and Slater 2013; Lugrin et al. 2016; Peck et al. 2013) assigns to the body a central role in the way we process and understand reality. Thus, investigating the potential to radically alter our bodies supports the exploration of the possibility to go beyond the current understanding of our cognition. Recent research is addressing the topic of embodying non-anthropomorphic avatars (Dörrenbächer, Löffler, and Hassenzahl 2020; Espositi and Bonarini 2023; Krekhov, Cmentowski, and Krüger 2019). Can we seamlessly enter bodies that are non-humanoid? What kind of change may such transformation mean for the perception of oneself (Karpashevich et al. 2018; Otterbein et al. 2022)?

To explore this relationship, we propose *My Robot Body*, a format for a workshop at the intersection between physical theatre and robotics. This has been implemented with five different social robots, non-anthropomorphic in shape and expressive in their movements. They are the "bodies" that the performers participating in the workshop should learn to animate, with their own bodies, to implement an integrated theatrical performance. Several wearable sensors can be attached to different parts of the body, and, through an app, it is possible to quickly configure which sensor controls which movement of a robot. This flexibility grants the participants total freedom of experimentation and creation.

Keywords Avatar, Robot, Embodiment, Human-Robot Performance, Workshop.
DOI 10.34626/2024_xcoax_010

The core idea of the workshop is to use a robotic control system to foster personal body awareness and interpersonal communication "without limits", investigating the possibility of interaction by removing factors of bias (Shamay-Tsoory et al. 2013; Lishner et al. 2008; Vanman 2016) and exploiting only minimal and essential features (Espositi and Bonarini 2023). Technology acts as a filter, allowing participants to create a common language that transcends social barriers through their bodies (Cuan 2021). The workshop structure draws heavily on techniques from physical theatre and improvisation, enabling participants to harness their own creativity and imaginaries (Jochum and Derks 2019; Murphy et al. 2011).

Through the complex machinery of this framework, where the robot actions seem to be the focus, participants are invited to discover their own bodies to infuse life into the robots (Jochum and Putnam 2017a), fostering self-exploration and body awareness (Fdili Alaoui 2019). The control devices capture movement, distance and sound signals; thus, the participants should find creative ways to "use themselves" to generate meaningful activity in the robots (Won et al. 2015; Zhou et al. 2021). Participants can see the effect of their own signals on the robots and modulate it accordingly (Cuan 2021). Moreover, since the interaction in this setting relies on non-verbal communication, the workshop aimed at stimulating the participants to create their own physical language to communicate with each other though the filter of the robots (Dörrenbächer, Löffler, and Hassenzahl 2020; Laroche et al. 2021), thus overcoming background and nationality biases.

Moreover, with *My Robot Body* we also wanted to develop a tool to promote digital literacy, fostering interaction between the public and new technologies (Das et al. 2018). The robotic control system of the workshop gives the participants a physical, experience-based opportunity to understand the mechanism of its technological components, software, sensors, and motors, in terms of names, functioning, strengths and limitations, addressing the gap between public perception and the robotics reality. Given the growing interest in human-centred factors in robotics research (such as aesthetics, culture and perception), we believe this is an important area for education and research (Jochum and Putnam 2015).

We believe that stage performance can be a promising testing setting for many hypotheses in human-robot interaction (Jochum, Borggreen, and Murphey 2014; Jochum and Derks 2019); it is a relatively constrained yet rich environment where a robotic agent shares its actions with a human partner (Hoffman, Kubat, and Breazeal 2008).

The workshop was led by a multidisciplinary team composed of engineers and a professional dancer. A research team and Computer Science students developed the technological system.

The presented framework encourages audience participation, thus allowing the participants not only to learn by observing, listening, and building, but also to express themselves in this novel manned-unmanned teaming structure to share their ideas, queries, and accomplishments (Cubero et al. 2021; Das et al. 2018). The personalized and participatory nature of the workshop encourages to get actively engaged.

2. Background

In this section, we report previous works about human-machine hybridization, focusing on applications in performing arts.

A lot of work has been done on the exploration of embodiment of avatars, mostly in virtual reality or videogame settings, investigating questions about the amount of human similarity needed to support embodiment (Argelaguet et al. 2016; Hosa et al. 2019; Kao 2019; Kilteni, Groten, and Slater 2012; Krekhov et al. 2019; Latoschik et al. 2017; Tekgün et al. 2022). Research on homuncular flexibility has shown the capacity of human bodies to re-adapt and control structures with different morphologies (Molnar and Menguc 2022; Steptoe et al. 2013; Won et al. 2015; Won, Bailenson, and Lanier 2016).

In performing arts, the avatar is often physical, a robot, operating in a physical environment where information can be obtained via our senses (Chen et al. 2011). If these avatars are paired with systems that act directly on the human body, the experience becomes fully centered on physicality. In this context, the stage environment can be controlled (Murphy et al. 2011) and offers a scaffolding for the creatures, since spectators are ready to suspend their disbelief (Jochum, Borggreen, and Murphey 2014). Moreover, artists are trained to look for creative solutions by exploring ambiguity and uncertainty, working at the boundaries of a given technology, transforming design and technological constraints into advantages (Jochum, Millar, and Nuñez 2017b).

Hybridisations with the machine differ in the amount of direct control that the human performer can exert, ranging from only being able to influence a pre-defined behaviour or algorithm, in what we can call "interactive", to total control of the machine, i.e., "puppeteering".

2.1 Interactive Systems

In interactive systems the human action influences pre-programmed behaviours of the robot agents.

The seminal work of (Pinhanez and Bobick 2002) introduced an artificial character that dynamically adjusts its behaviour based on spectators' and actor's actions. Performance details like intensity, gestures, pauses, and audience interaction change according to other actors' performance and audience reactions.

"The Dynamic Still" (Jochum and Derks 2019) explores improvisation and choreography between humans and robots, aiming to develop real-time interactions and motion algorithms for human-robot engagement. It focuses on mapping motion algorithms to a wheeled cart-like robot based on human dancer movement patterns, emphasizing spatial awareness and orientation over representational gestures.

"Mimus" (Gannon 2017) is an installation featuring an industrial robot equipped with eight ceiling-mounted depth sensors. These sensors track viewers' movements and analyse attributes such as age and engagement level. Based on this data and a programmed set of animal-like behaviours, the robot interacts with the "most interesting persons" by approaching them. This creates a closed affect loop where the robot's actions influence the viewers' reactions, and vice versa.

In (Hoffman, Kubat, and Breazeal 2008), a robotic puppeteering system is developed and employed in a theatrical production involving one robot and two human performers. The system's interface combines reactive gestures and parametric behaviours, enabling the puppeteer to control pre-programmed motions of the robot. The aim is to allow a single operator to control the robot's behaviours while transitioning to autonomous subsystems. Despite physical distance, the operator feels the need to synchronize actions with the robot, as though he was interacting with humans.

2.2 Total Control: Puppeteering

In puppeteering human operators fully control the avatar.

In (Jochum, Borggreen, and Murphey 2014), robotic marionettes are featured in live performances. Motion capture technology is utilized to animate the robots indirectly, by capturing string configurations to move the marionettes. Puppeteers must compromise with the physical dynamics of the puppets, as these resist direct manipulation, to create believable and expressive characters during the performance.

In (Murphy et al. 2011), the robot puppets were seven radio-operated aerial vehicles which, despite their limited degrees of freedom, demonstrated expressiveness, enhancing the emotional impact of the play.

"Piano&Dancer" (Palacio and Bisig 2017) featured a dancer controlling an electromechanical piano through physical movement.

In "OUTPUT" (Cuan 2021), an industrial robot serves as a dancing body, allowing a human to dance alongside it. The artist mapped the robot's joints onto her limbs or entire body, creating a human dance sequence inspired by physical labour. This sequence was performed by both the artist and the robot, in an interactive feedback loop where the artist modified her choreography based on the robot's movements. The artist experienced a sense of being "inside the machine," feeling as if her body had extended into the robotic device.

The authors of (Jochum, Millar, and Nuñez 2017b) explore creative strategies for robot design and control in live performances: soft design, voodoo control, and hybrid control. Inspired by traditional puppetry, these aim to create expressive, fluid movements for large-scale robots closely interacting with humans. The focus is on expressive movement more than on functionality, leading to innovative design and control solutions with potential applications beyond entertainment in human-in-the-loop systems prioritizing expressiveness and intuitive interfaces.

In (Espositi and Bonarini 2023), an interactive installation linked participants' bodies to sensorized dog leashes, serving as controllers for a robot puppet in real-time. The controller space was separate from the robot's space, with participants unaware of the connection. This passive link enhanced immersion and transmitted nuanced qualities to the robot, resembling a living being. The localized action of the multiple controllers altered proprioception, fostering a sense of body rediscovery for participants.

Finally, technology can be used to act directly onto the body to actively modify its perception (Espositi and Bonarini 2023). In (Jochum et al. 2018), exoskeletons merge human and robot motions, while (Karpashevich et al. 2018) explores active costumes altering dancer experiences. These designs inspire novel movements, fostering new aesthetics and character embodiments. In (Otterbein et al. 2022), wearable technology's impact on movement and self-perception is explored through artistic methods, showing how wearables can influence movement even without auditory or visual feedback. (Gemeinboeck and Saunders 2017) use choreographer insights to design non-anthropomorphic robots, employing a wearable "costume" or "prosthesis" to extend a dancer's body and explore machine embodiment. Like our own aim, the authors wanted the dancer not to just unilaterally control the movement of the object but rather to develop movement with it.

3. The System

In this section, we describe the technical system that we implemented to support the workshop. It is made of three interconnected components:

- The robots, the non-anthropomorphic bodies that the participants had to animate.
- The controllers, the wearable devices that the participants used to transform their actions into movements of the robots.
- The app, the central hub that makes it possible to reconfigure the control mapping at any time.

3.1 The Robots

The robots are the entities that the participants will embody, materializing actions induced by the control devices. Real robots provide the opportunity to create diverse body types and can be deployed in real-world settings to interact with physical environments, objects, and people, including theatrical stages (Henning and Lindelof 2020). These robots are not autonomous, but completely under the control of the participants, acting as avatars (Cuan 2021; Jochum, Borggreen, and Murphey 2014; Otterbein et al. 2022).

Robots are characterised by:

- their degrees of freedom (DoFs), determining the range and type of movements they can execute. Each DoF operates independently and is controlled by a distinct signal from a control device.
- their appearance: we emphasised novel and disruptive body structures rather than biomimicry. Robots may be stationary or mobile, with parts capable of movement and configuration changes, and their size influences their interaction capabilities.

The workshop utilised five robots to offer participants a diverse range of characteristics to experiment with. Key differences among the robots included their mobility (fixed vs. wheeled), the degrees of freedom number and type (mechanical movements, lights), which influenced controllability and the level of detail in actions, height (affecting impact on spectators), and materials/appearance, which influenced the robot's "character" and overall aesthetic and emotional effects of movements.

Siid, the flower robot

Siid (Fig. 1) is a flower-shaped robot with a total of 7 controllable degrees of freedom (DoFs). It can rototranslate using omni wheels (3 DoFs), and its petals can open and close (1 DoF). Additionally, it features an LED inside its bulb that can vary in intensity (1 DoF), and its digital eye's pupil can move along an eye-like screen (2 DoFs). It has a height of 70cm and is the most bio-inspired of the robots. The contrast between its rigid shell and soft head is underlined by the movement of the petals, which adds mystery and allows for significant changes in its appearance.

Fig. 1 The robot *Siid*. Controlled by a participant with motion of the wrist and head.

Odile, the "robot-like" robot

Odile (Fig. 2) is characterised by two mechanical arms of different lengths: a short one, serving as the head, capable of forward and backward movement and rotation of the tip in multiple directions, and a long one, functioning as the arm, capable of intricate movements, including articulated movement of the end-effector. Odile has 13 DoF, and did not move in space in this workshop; its appearance is explicitly robotic, a baseline for robot aesthetics.

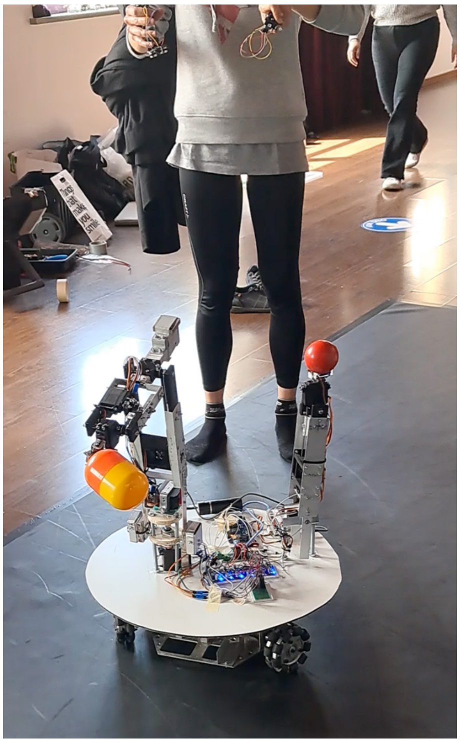

Fig. 2 The robot *Odile*. Controlled by a participant with distance.

Blackwing, the winged robot

Blackwing (Fig. 3) is equipped with omni wheels for rototranslation (3 DoFs) and a servo motor that controls two long thin poles, extending or contracting elastic fabric between them to create wing-like movements. An additional servo enhances the expressivity of the fabric by adjusting the frontal movement of the pelvis, effectively turning it into a sail, totaling 5 DoFs. Its aesthetic is characterized by black fabric covering its body, lacking an explicit face, thus maintaining a neutral appearance that directs focus towards its movement.

Fig. 3 The robot *Blackwing*. Controlled by a participant with sound and motion of the head and wrist.

Scarecrow, the plastic dancer

Scarecrow (Fig. 4) is a robot designed to experiment with the expressivity of plastic sheets. It consists of a tall wooden cross structure mounted on an omni-wheel base that can rototranslate (3 DoF). The wooden structure, over 1.70 meters tall, is covered with thin plastic sheets with long hanging parts. Scarecrow's expressivity comes from the interaction between air and the sheets, resulting in a slow and soft, ghost-like floating motion that can be controlled by the movement of the base. With only 3 DoF in the base, Scarecrow is the least actuated and tallest of the robots.

Fig. 4 The robot *Scarecrow*. Controlled by a participant with sound.

Sonoma, the wooden dancer

Sonoma (Fig. 5) is a robot with 6 degrees of freedom (DoFs), 3 DoFs on omni-wheels and a 3-DoF arm that resembles a sickle, beak, or claw. It features a large gown on its lower body, which accentuates its rototranslational movement and responds dynamically to it. Sonoma stands at a total height of 120cm, making it the second tallest robot. Its arm can extend outward by over 1.5 meters, allowing for highly noticeable and unexpected expressive behaviours. Sonoma combines a human-recalling element, the gown, with an abstract wooden arm, creating a disruptive blend that encourages exploration and expression.

Fig. 5 The Robot *Sonoma*. In the foreground, in the company of the other robots.

3.2 Control Devices

A control device enables a mapping between the participant's and robot's movements, gathering data from sensors and transmitting them to the robots.

In the design of the control system, we followed these guidelines:

- Engaging Control Mapping, to encourage novel use of body DoFs, such as utilizing unconventional postures (Steptoe et al. 2013; Krekhov et al. 2019) or remapping existing ones (Won et al. 2015).
- Flexible Remapping, allowing for control adjustments to accommodate user preferences, with some favouring natural mappings while others proposing challenging, more immersive ones (Steptoe et al. 2013; Won et al. 2015).

We designed three types of control devices, each associated with a specific sensor: accelerometer, sonar, and microphone. Multiple copies of each type were produced, totalling 22 devices, to enable parallel experimentation by participants (Fig. 6).

Each device operates independently with its own power source, and includes the sensor, an ESP32 module with an integrated battery case for power, control logic and WI-FI, and a 3D printed case with interfaces for velcro straps for easy wearability on any body part. Each device measures 3x3x15 cm in size.

Fig. 6 The ***Control devices***. From left to right: accelerometer, sonar and microphone types.

The three types of devices are described in the following.

Accelerometer

The accelerometer device uses an MPU6050 accelerometer sensor to capture angular data. Upon activation, it establishes a reference frame based on the initial position and produces angular displacement along three axes. This enables the device to capture three independent control signals, each symmetrical around the "zero" position, spanning from "-max_absolute_value" to "max_absolute_value" on each axis. The max absolute value can be adjusted in real-time to alter the granularity of the sensor signal and the range required to cover the full movement of the corresponding degree of freedom.

Sonar

This device utilises a sonar sensor to capture distance data. It measures distances from 0 (minimum or invalid reading) to a maximum value, which can be adjusted in real-time. The device offers flexibility as distance can be manipulated in various ways: it can measure distances between participant's body parts or with respect to external objects such as walls or the floor, and even other participants that can interact by acting as obstacles for each other, altering their relative positions in space.

Microphone

The Microphone device features a microphone that collects sound intensity. It has a high threshold to filter out background noise and only capture voices very close to the sensor. The data range spans from 0 (sound below threshold) to "max_intensity", which can be adjusted in real-time. The objective is to enable participants to explore radical transformations between sound and movement, where their voices directly control robotic movements. This encourages the production of sounds solely by volume modulation, enabling yet a different layer of body awareness.

3.3 The App

The most crucial aspect of the entire system is the possibility to reconfigure the control mapping easily and at runtime, to foster experimentation and to make the system as natural to use as possible, reducing the gap between the participants and the technological aspects. To do this, we created an app that communicates with the robots and the devices at runtime. Its purpose is to enable the dynamic reconfiguration of connections between robot degrees of freedom (DoFs) and specific signals from the control devices.

The app was always operated by facilitators, and participants could ask at any time to reassign connections between a control device and a specific robot DoF, which was done using the app interface.

The app uses a configuration file to connect the characteristics of each robot's DoFs to the type and setting of sensors for each control device. It allows for the adjustment of sensitivity by modifying sensor ranges and thresholds. Additionally, the same control signal can be assigned to control multiple DoFs simultaneously, even across different robots. This flexibility allows for exploration of different effects of the same actions transformed into diverse robot movements.

4. The Workshop

This Section describes in detail how the workshop was structured.

Facilitated by an engineer with a theatre and dance background and a professional dancer, it spanned one day from 10 am to 6 pm with a lunch break. It took place in a theatre with professional dance floors.

The structure included an icebreaker, reflection on participants' initial imaginaries, warmup focusing on dance and body awareness, introduction to technology, guided and autonomous experimentation, creation of performances, and concluding reflections and farewells.

Each section is introduced here below, addressing its aims and relevance for the workshop.

4.1 Icebreaker: why you are here

The session began with an icebreaker activity where participants introduced themselves, their backgrounds, and their interests related to the workshop topics. Participants came from diverse backgrounds including scenography, performative arts, engineering, and dance. Their common interest lay in experiencing new technologies firsthand, particularly those that are intriguing but often inaccessible to non-technical environments due to the lack of available contexts and systems.

4.2 Reflection: your imaginaries

The diverse participant backgrounds, with varying levels of exposure to technology and robotics, brought great richness to the workshop. To tap into their unfiltered imaginations, participants were initially asked to express their perceptions of these technologies through words, sentences, or images without prior exposure to the robots and control devices. This exercise aimed to spark reflection while crystallising the initial preconceptions that we aimed to modify throughout the workshop. The papers containing their expressions were collected and set aside for later use.

4.3 Warmup: dance and body awareness

This last session before the introduction of the technology aimed to activate participants' bodies before interacting with the machines, achieving two objectives: establishing the workshop space as one where the body is used differently and fostering positive group dynamics free from mental constraints. Participants engaged in a brief stretching phase followed by a dancing game where they moved freely in the centre of a circle while others imitated them. The increased body temperature prepared them for smaller group activities, where one participant at a time moved freely while others acted as soft, viscous resistances, enhancing perception of even the smallest movement details.

4.4 Discovering the Technology: the first steps

Participants were now introduced to the robots and devices. The main objective was to explain the system comprehensively, covering robot movements, device sensors, and app functionalities. To manage the high amount of information, this phase was structured to be practical. Participants were asked to volunteer one at a time and directly try the control devices on different robots, as the facilitators explained device functions and robot movements and demonstrated how control devices could be worn on the body (Fig. 7). Computer engineering students continually reconfigured control mappings using the app to demonstrate how a single control device could span all robot degrees of freedom.

Fig. 7 First contact with technology. Hands on introduction to the control devices, app functioning, and robot motions.

4.5 First Experimentation: guided

Participants were divided into small groups and assigned to specific robots. Each group was given a simple task, such as moving the robot from point A to point B. Participants had the freedom to choose control devices and mappings to achieve the objectives. Facilitators moved between groups to provide guidance, stimulate creativity, and encourage different approaches. Participants were encouraged to start with fewer controllers and gradually increase them over time (Otterbein et al. 2022). After 30 minutes, groups shifted to a different robot for a total of two rounds, allowing all participants to familiarize themselves with all three types of control devices.

4.6 Reflection: expressive potential of everyday objects

After the lunch break, a second reflective moment was introduced to leverage the change in pace. Participants formed a circle as facilitators passed around everyday objects such as tape, a wheel, a piece of paper, a pen, and a broken mechanism. Each participant shared their thoughts and imaginations about how these objects could come alive, drawing from personal experiences or improvising on the spot. Afterwards, participants examined the robots closely, considering materials, shapes, and sharing initial impressions or reflections with the group. This activity aimed to stimulate participants' imaginations and encourage them to exchange ideas, preparing them for subsequent phases where they were more autonomous in creating narratives.

4.7 Second Experimentation: autonomy

This phase was similar to the first experimentation of Section 4.5, but participants were now given significantly more freedom. No specific groups or tasks were enforced, and participants were not required to focus on any particular robot. Instead, they were encouraged to freely experiment either individually or in groups with any aspect they found interesting (Fig. 8). Facilitators supported participants' creative choices by suggesting different approaches, providing ideas to those in doubt, and encouraging changes when participants remained stuck on specific configurations. The goal was to ensure that by the end of this phase, all participants had experimented with all robots and devices at least once.

Fig. 8 Free experimentation: autonomously exploring the possibilities of the robots' and one's own bodies.

4.8 The Final Presentations: creating the performances

Participants transitioned from guided (Section 4.5) through autonomous exploration (Section 4.7) into the final stage. They were tasked with creating their own performance using the devices and robots in any way they preferred. Participants gathered in a circle, and the papers they had written or drawn earlier (Section 4.2) were collected, grouped by theme, and placed on the floor. After reading them, participants stood next to the group that resonated with them the most, forming two groups. Each group was then given 40 minutes to create a scene, lasting no more than 3 minutes each, using the chosen papers as title and themes. Participants could incorporate music, and facilitators supported them throughout the creative process. Finally, both groups presented their scenes to the others (Fig. 9; Fig. 10).

Fig. 9 Final scene: *"In Sync"*. Collaboratively controlling *Blackwing* with *motion*.

Fig. 10 Final scene: *"Elastic"*. Competing to control *Scarecrow* with *distance.*

4.9 Reflection: Discussion and farewells

The workshop concluded with a final reflection session. Participants gathered in a circle, and the papers created earlier were returned to their respective authors. Everyone shared their impressions, emotions, and how their initial expectations compared to their actual experience. Finally, the facilitators invited the participants to share ideas for improvements for future developments.

5. Discussion

The activity involved two groups of participants. The first group consisted of Computer Science students who worked alongside the research team on the software and control devices for the robotic system over a 3-month period as part of a university project. After the development phase, they served as supporting facilitators during the workshop, gaining insights into the system's strengths and limitations and finding solutions to arising issues. Their role as facilitators also provided them with exposure to a different context from their usual environment and allowed them to interact directly with the participants. The second is the group of the participants, with diverse backgrounds and ages, including dancers, performers, engineers, actors, arts and scenography students, a choreographer, and an acrobat, aged between 22 and 45, hailing from Italy, Serbia, and Russia.

Initially, participants preferred the microphone sensor due to its ease of use and intuitive nature, enjoying the seamless translation of sound modulation into movement. However, as the workshop progressed, the accelerometer and sonar became more prominent despite being initially challenging to master. These sensors encouraged diverse body movements and interactions, unlike the microphone, which limited movements due to its need to be kept close to the sound emitter. Participants rarely utilized all three angles of the accelerometer simultaneously due to sensitivity issues, preferring to distribute multiple accelerometer devices across the body. Sonar received the most positive feedback overall, combining the simplicity of the microphone with the body involvement of the accelerometer and offering diverse creative solutions. Participants demonstrated high levels of experimentation, using various elements such as each other, space, and the robots themselves to transform data into robot movement. They also explored unconventional uses of control devices, such as attaching them to sticks or wheels, leaving them in specific positions in space, or combining them to form complex devices.

When controlling robots in groups, two main approaches emerged: collaboration, where participants coordinated to create cohesive movements, and playful competition, where they intentionally generated incoherent movements for the robot. Except few moments of extreme experimentation, participants generally preferred using no more than two devices simultaneously. Concentration was required to use and monitor device effects on the robots, and this made handling more than two devices at once challenging. Instead, participants preferred using the same devices across multiple robots to control more degrees of freedom simultaneously, indicating that it was easier to focus on device usage and monitor their effects on the robots rather than on themselves.

As the workshop progressed, participants preferred robots with fewer degrees of freedom (DoFs) for easier coordination and clearer actions. Odile, with its 13 DoFs and inability to move in space due to technical issues, was quickly abandoned due to complexity and coordination challenges. Siid and Sonoma, despite their richness, were appreciated, but participants focused on a subset of their DoFs. Interaction and coordination were highest with these robots, requiring small groups to leverage their expressive potential. Focus shifted to Scarecrow and Blackwing, which could be controlled expressively with one or two devices, allowing participants to manage choreographies alone. Scarecrow, especially, was preferred for free experimentation, with participants using the microphone to control its floating movement. Consequently, these robots were chosen for the final performances.

These findings suggest that the more complex robots are very relevant to foster creativity and experimentation, but to properly leverage them it would be necessary to rethink our system based on independent control of each DoF, which is feasible for very simple structures, while more complex ones, like the 6DoF arm of Odile, could be more naturally controlled by acting directly on the end-effector, rather than on all the joints independently.

Participants observed a discrepancy between their actions and the corresponding robot movements, particularly when controlling robots with slower dynamics. For instance, controlling Sonoma's wooden arm's lateral movement with an accelerometer placed on a participant's hand resulted in challenges due to the different speeds of human and robot actions. While participants could cover the accelerometer's signal span quickly, the corresponding movement on Sonoma's arm was slower due to its weight and size. This often led to playful attempts to move faster than the robot, but the experimentation proved less interesting than the opposite, when the participants adjusted their bodies to match the robot's dynamics. A future direction may be to add mechanisms that act directly on the participant's body, to force them to follow the dynamics of the movements that are mapped, as in (Dörrenbächer, Löffler, and Hassenzahl 2020; Espositi and Bonarini 2023). Moreover, in the absence of such a feedback system, it is difficult for the participants to really understand the effort that the robot's movements require. This led to the robot Sonoma breaking, after being overworked as mentioned before.

The workshop initially aimed to enhance body awareness by allowing users to transform their movements into actions of different bodies using novel technologies. Interestingly, a significant additional finding was that the workshop effectively promoted digital literacy. Participants gained hands-on experience using sensors with their bodies, understanding their potentials and limitations, and witnessing data transformation into mechanical actuation. The seamless reconfigurability of the technology facilitated experimentation with various configurations, masking complexity. Participants unanimously recognized this as a relevant takeaway, suggesting the workshop's potential as a learning tool.

Participants found the workshop to be both instructive and enjoyable, leading to a shift in their perspectives regarding the devices and their potential impact and use in innovative performances. They suggested that a two-day intensive workshop would be optimal given the novelty and density of the topics. Additionally, they emphasized the need for more intuitive controls for complex robots and mechanisms to enhance the sense of connection between participants and the robots they control.

6. Conclusions

We developed the blueprint of a workshop based on immersive control of non-anthropomorphic robotic bodies.

The workshop combines advanced technology with dance and theatre methods to offer a comprehensive experience. It includes five distinct social robots with diverse characteristics and capabilities, along with three types of wearable control devices corresponding to different sensors (accelerometer, sonar, microphone). Additionally, an accompanying app enables real-time adjustment of mappings between robots and controllers, enhancing flexibility and adaptability during the workshop.

The *My Robot Body* workshop spanned one intensive day and was conducted twice for a total of 11 participants in a theatrical setting. It integrated techniques from creativity, dance, and theatre to encourage participants to explore their imagination and engage with their bodies in a new way. The technological system, including various robotic bodies and control devices, was well-received, stimulating participant interest and facilitating experimentation, even beyond the initially envisioned possibilities.

As participants became more skilled with the controllers and sought to create coherent movements in the robots, they shifted their preference towards less complex robots that could be fully controlled by a single person. Similarly, participants typically used no more than two controllers simultaneously due to the high coordination required to use them precisely.

Participants identified a limitation in the system regarding the "distance" between controller actions and the corresponding robot movements, which led to a sense of disconnection. The disparity in dynamics between the fast movements of participants and the slower movements of the robots occasionally resulted in playful behaviours, but ultimately created a disconnection. This mismatch in speed also caused strain on the robots, leading to one of them breaking due to being overloaded by participants unaware of the strain caused by certain movements.

Participants expressed a high level of satisfaction with the workshop, noting a shift in their perspective on new technologies and an increased level of body awareness. They reported experiencing an "out of body" sensation when focusing on controlling a robot for extended periods, feeling their familiar body motions being translated into movements of a new body. Additionally, the workshop was seen as an effective learning tool for fostering digital literacy, as participants were able to directly engage with sensors and actuation, gaining first-hand experience of their potentials and limitations in a seamless context of physical experimentation.

6.1 Future Directions

Future instalments of the workshop will require two major improvements.

High-level control

Participants in the workshop preferred simpler robots as they were easier to control by acting on each independent joint or minimal unit of movement. This method of control was more compatible with rototranslation speeds and movements requiring the action of a single actuator, such as opening and closing motions of petals or wings. In future versions, complex types of motions like the end effector of a flexible arm should be aggregated to create more intuitive DoFs.

Connect the participant's and the robot's motions

Currently, any control device can be linked to any type of motion of any robot, regardless of the motion's type and dynamics. This sometimes creates a disconnection between the participants and the robots. Participants may not realize the required dynamics of the robot's movements, leading to frustration or playful challenges that could result in damage. In the future, integrating control devices with active feedback systems will provide sensations or restrain participant movements based on the controlled DoFs, enhancing the connection between participants and robots.

Finally, following the suggestions of the participants, future versions will be structured to last longer, and to provide a wider range of control devices, while at the same time incorporating monitoring systems that capture the data on the participant's use of the devices to provide clear numerical data for analysis, as a measure for the results.

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