

Master Thesis Project

I think it was Nervous too: Moving with Robots

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I think it was Nervous too: Moving with Robots

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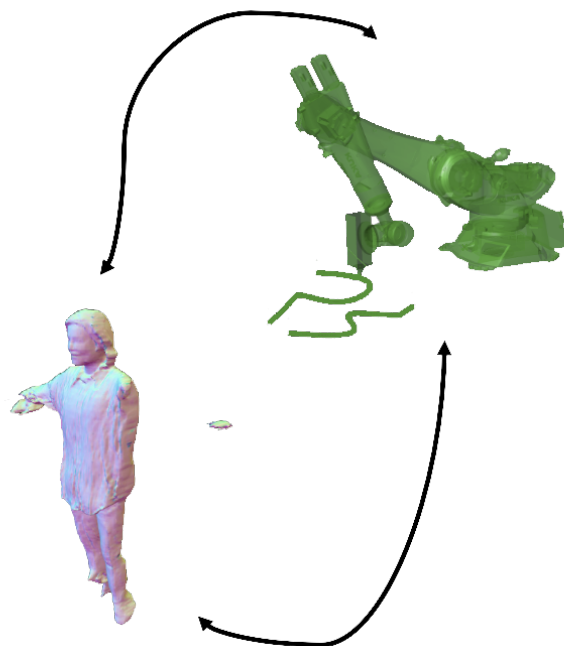
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Abstract

The objective of the following work is the making of a human-robot experience, with a focus on the bodily connection to robots in a movement scenario. I propose an artistic exploration of the dynamic between humans and machines, investigating bodily sensations in human-robot interactions (HRI). The artistic research project was realized in cooperation with the Creative Robotics Lab, Linz to produce a movement experiment, that enables a real-time human robot experience. Bodily sensation mapping (BSM) was used as a self-reporting tool to assess physical and emotional experiences humans have when engaging with robots. To begin with, experiments were carried out, in which participants were invited to interact with a robot and later asked to draw their bodily sensations in a body silhouette. Through BSM data was collected and translated by dancers into a movement score, resulting in a choreography. This creates a circular process where actors, humans and robots, influence each other. Robots' motion design is inspired by human physique as to imitate the efficiency of natural movement. Dance offers the possibility to explore movement scenarios beyond that. Performative approaches function as an expression of an interaction. The outcome of the project is an installation, showing the results of the movement experiments, with a live demonstration of the movement score that was generated through the process.



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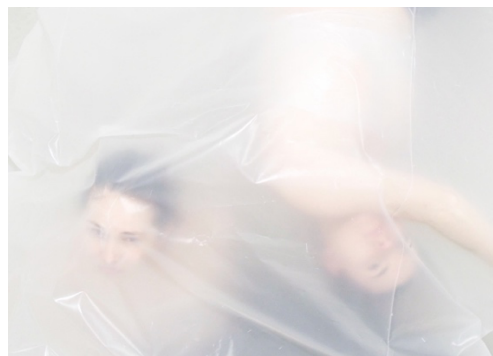
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Preface

Before starting this project, I developed a piece in my very first year of the study program, called *Hyper-Spinal Retrograde*. This project laid the foundation and the starting point for my Master thesis. Hyper-Spinal Retrograde consisted of a video installation and a live performance with two dancers, Alba Glatz and Su Huber. In July 2023 it was exhibited and performed at Künstlerhaus Vienna, within the exhibition Licking Structures by the Art & Science department of the University of Applied Arts Vienna.

The project explores the boundary between the physical and digital realms. Body, gender, and media tools are in the process of digital liquefaction. Immersive media art crosses contemporary dance to experiment with how bodies interact with technology, how technology changes the way bodies connect, and how body modification comes into play. Sensors, cameras, displays and the skin act as an interface in a fluid world. Using different media, such as physicality – body, texture materiality – objects, auditive engagement, animation and real-time audio-visuals, the project aims to create a sensorial world that exists in contrast to binary encounters, definitions, and experiences.¹

Within this project, I already examined the ways bodies are seen, but also how bodies experience their environment. Based on this, I looked at the bodily sensations, that occur when humans and robots move together in my Masters' thesis. In the process of making the project Hyper-Spinal Retrograde I noticed that humans have individual reactions engaging with technology and that they embody these reactions differently. For my thesis project I wanted to focus on a specific technology, namely robotics. I worked with the idea of a future scenario in which robots are omnipresent and wondered how people would deal with that. This process led to the artistic research project, of conducting body sensations in a movement scenario with a robot.



*Figure 1: Image taken at the video shooting of Hyper-Spinal Retrograde I.
Picture taken by Silas Isenmann May 05, 2023.*

¹ Art & Science „Hyper-Spinal Retrograde“. Accessed on May 11, 2025. https://artscience.uni-ak.ac.at/works/hyper-spinal_retrograde

Project Outline

I think it was Nervous too: Moving with Robots is a mixed-media installation and performance piece with two dancers. This project was enriched and implemented by various cooperation partners, including Amir Bastan, a researcher and artist at the Creative Robotics Lab in Linz.² Furthermore, two dancers, Sara Heitzinger and Charlotte Safar, were involved in the process and development of the final choreography. The process went through three phases, starting with literature research, followed by the development of an artistic experiment and finally the translation of the outcome into an installation and live demonstration. Fundamentally, the project deals with emotional and bodily responses to robotic movements. The literary research serves as a framework for understanding the experimental approach and the artistic realization. The text gives an insight into the history of robotics, a brief overview of performing arts with robots and selected artistic references. Secondly, an artistic experiment was developed and documented in cooperation with the Creative Robotics Lab in Linz, which addresses the research question “What kind of body sensations occur when moving with robots?”. The term *experiment* refers in this thesis to an artistic exploration and does not aim to prove a hypothesis. A wide range of material and feedback was collected by using different tools like video recordings, questionnaires and body sensation mapping. Lastly, all the collected material was used to gain a diverse overview and understanding of the objective, to then condense the process into a movement material. In this thesis project dance is used as a method to bring experimental components into an experiential space. Thereby the individual experience of moving with robots is transferred into a performative process that is perceived by an audience. Although this takes place collectively, the transfer of body sensations also happens on an individual level. Every spectator receives the body sensations in an individual way. The project contributes to examining the movement possibilities in human-robot interaction that go beyond functionality.³

² Website „Creative Robotics“. Accessed on May 11, 2025. <https://creativerobotics.at>

³ Maguire-Rosier K. et.al. „What Other Movement Is There? Rethinking Human-Robot Interaction through the Lens of Dance Performance“ p.90

Introduction

Decades ago, ideas around human interaction with robots used to be science fiction. Like Karel Čapek's play *R.U.R.*, or the short stories by Isaac Asimov.⁴ The multidisciplinary field of human-robot interaction (HRI) emerged in the mid 1990s.⁵ The core of the field is to design, understand and evaluate the usage of robotic systems by or with humans.⁶ Asimov's stories from the 1940s coined the term *robotics* and raised crucial questions concerning human-robot interaction. In 2025, these became fundamental research questions in the discourse of HRI and far removed from the days of science fiction.⁷ By nature HRI is a problem-based research field and involves various disciplines. It requires collaboration and generates a community of theorists and practitioners.⁸ To create a successful human-robot interaction designers, engineers, anthropologists, psychologists, philosophers and sociologists etc. have to be involved. Together, they develop the software and hardware of the robot, analyze the human behavior when engaging with the robot and create the robot's embodiment and behavioral style to convey a specific aesthetic.⁹ Human and robotic movement influence each other in HRI.¹⁰ However, research about robotic movement is dominated by approaches concerned with speed and efficiency. When it comes to movement and bodily interaction dancers provide an expertise that allows them to design through bodily expressions. Involving the discipline of dance into HRI provides the opportunity to explore robotic movements beyond the concerns of efficiency.¹¹

Bits of History

Robotics has a long history dating back to Homer in ancient times, who reports about the mechanical maidens in 850 BC. Hephaestus, the Greek god of smithing and craft, made the maidens out of gold, to assist him in his work.¹² In the 15th Century Leonardo Da Vinci sketched humanoid automatons, which looked like a typical German-Italian suit of armour and was

⁴ Bartneck C. et.al. „Human-Robot Interaction - An Introduction“ p.6

⁵ Goodrich M. A. and Schultz A. C. „Human-Robot Interaction: A Survey" p.211

⁶ Ibid. p.204

⁷ Bartneck C. et.al. „Human-Robot Interaction - An Introduction“ p.6

⁸ Ibid. p.9

⁹ Ibid. p. 9-10

¹⁰ Maguire-Rosier K. et.al. „What Other Movement Is There? Rethinking Human-Robot Interaction through the Lens of Dance Performance“ p.88

¹¹ Ibid. p.89

¹² The MIT Press Reader “Surveillance, Companionship, and Entertainment: The Ancient History of Intelligent Machines”. Accessed March 11, 2025, <https://thereader.mitpress.mit.edu/the-ancient-history-of-intelligent-machines/>

inspired by ancient Greek texts.¹³ Later in the 1730s Jacques de Vaucanson built a mechanical duck that was capable of flapping its wings, eating, and digesting grain. Pierre Jaquet-Droz, a clockmaker from Switzerland, built three humanoid automatons in the 1770s. The three automatons consisted of the draughtsman, the musician and the writer.¹⁴ The interplay of art and robots can be found in literature and theatre. E.T.A Hoffmann for example wrote the classic gothic novel *Der Sandmann* in 1815 featuring the figure *Olimpia* an automaton.¹⁵

The term *robot* was coined by Karel Čapek's play *R.U.R*, which stands for Rossum's Universal Robots.¹⁶ The Czech drama premiered on 25 January 1921 and talks about a chemist called Rossum, who created a formula to produce human-like machines, that function as optimized workers.¹⁷ At the beginning of the play, the unopposed, mechanical labour force ensures prosperity and social peace. In the course of the play, however, there is a revolt as the robots empower their emotions. As a result, humanity is wiped out. The robots have an expiration date and only two remain the androids Adam and Eve form a new civilization, the only ones who can reproduce themselves.¹⁸ The Czech term *robota* means hard work or forced labour and did not come from the author but his brother Josef Čapek. In this sense, an early science fiction drama managed to create a word that passed over into everyday language. *R.U.R* did not only introduce the term *robot* but also addresses topics that are still relevant in research today.¹⁹



Figure 2: Screenshot, Article by Florian Baranyi, ORF "100 Jahre Roboter". Image of (from left to right) Karel Čapek, Josef Čapek, and author Vitezslav Nezval, Czechoslovakia 1933. Last Accessed February 21, 2025.
<https://orf.at/stories/3197959/>

¹³ Museo Galileo "Leonardo's robot". Accessed March 12, 2025, <https://brunelleschi.imss.fi.it/genscheda.asp?appl=LIR&xsl=slideshow&lingua=ENG&chiave=101791#:~:text=This%20robot%20would%20influence%20his,more%20versatile%20general%20purpose%20robots>

¹⁴ The New York Times "Automatons and Ingenuity". Accessed March 12, 2025, <https://www.nytimes.com/2012/03/08/fashion/08iht-acaw-jaquet08.html#>

¹⁵ Apprich C. "Dancing with Machines: On the Relationship of Aesthetics and the Uncanny" p. 123

¹⁶ MIT Press „R.U.R. and the Vision of Artificial Life“. Accessed February 21, 2025, <https://mitpress.mit.edu/9780262544504/r-u-r-and-the-vision-of-artificial-life/>

¹⁷ ORF „100 Jahre Roboter“. Accessed February 21, 2025, <https://orf.at/stories/3197959/>

¹⁸ Ibid.

¹⁹ MIT Press „R.U.R. and the Vision of Artificial Life“. Accessed February 21, 2025, <https://mitpress.mit.edu/9780262544504/r-u-r-and-the-vision-of-artificial-life/>

The *Three Laws of Robotics* were invented by the author Isaac Asimov and published in his short story *Runaround* in 1942, which was later included in his book *I, Robot*.²⁰ In *Runaround* two scientists are on the planet Mercury to investigate whether a mission can be continued with the help of robots. Working with the robots put the scientists into a life-threatening situation. In their search for a solution, they came across the *Three Laws of Robotics*, which saved their lives.²¹

A robot may not injure a human being or, through inaction, allow a human being to come to harm.

A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.²²

Invention and Development

George Devol invented a method of controlling machines in 1954, which he patented. The American inventor built the first industrial robot called *Unimate* in 1956 (granted 1961), which was used for material handling in factories.²³ Known as the *Father of Robotics* is the U.S. engineer Joseph Engelberger, who worked closely together with George Devol. Engelberger founded the world's first robot manufacturer company called Unimation.²⁴ The *Stanford-arm* with 6-degrees-of-freedom (6-dof), was designed in 1969 by Victor Scheinman, one of the first robots exclusively made for computer control.²⁵ The first anthropomorphic robot *WABOT-1* was developed by the Waseda University in 1970 – 1973, consisting of various systems like limb control, vision and conversation. This system enabled the robot to communicate with a person in Japanese. For this research project, four laboratories of the Waseda University joined forces, to create the anthropomorphic robot.²⁶ The first major boom in industrial robotics occurred in the 1980s, during which millions of Japanese yen were invested in the sector.²⁷ DLR, the institute for robotics and mechatronics developed a lightweight robot in 1995, originally meant for tasks in space. The *LBR 1* (lightweight robot 1, see *Figure 3*) had 6 joints.

²⁰ Stanford Engineering “Robotics: A Brief History”. Accessed March 12, 2025, <https://cs.stanford.edu/people/eroberts/courses/soco/projects/1998-99/robotics/history.html>

²¹ Ibid.

²² Ibid.

²³ Ibid.

²⁴ MIT Press “Robotics in Service”. Accessed March 12, 2025, <https://mitpress.mit.edu/9780262525664/robotics-in-service/>

²⁵ Info Lab Stanford „Robots and their Arms”. Accessed March 12, 2025, <http://infolab.stanford.edu/pub/voy/museum/pictures/display/1-Robot.htm>

²⁶ Waseda University Humanoid “WABOT Waseda roBOT”. Accessed March 12, 2025, https://www.humanoid.waseda.ac.jp/booklet/kato_2.html

²⁷ Bechthold M. “The Return of the Future: A Second Go at Robotic Construction”. p.116

Later in 2000 the team of DLR created *LBR2*, which consisted of 7 DOF (degree of freedom), this invention made the kinematics of the robot similar to that of a human arm.²⁸



Figure 3: LBR I.

Last Accessed March 12, 2025. <https://www.dlr.de/en/rm/research/robotic-systems/arms/lwr-i-1991-1996>

The term *cobot* was coined by Brent Gillespie and a project team supported by the General Motors Foundation. In 1996 James Edward Colgate and Michael A. Peshkin designed the first cobot at Northwestern University. Initially they called a cobot *programmable constraint machines*.²⁹ It took until 2015 that Human-Cobot interaction became relevant in assembly.

There is a wide range of forms and types of robots generally categorized by the field of application, such as industrial, domestic, medical, service, military and entertainment robots. However, the diversity of robotics extends far beyond these categories. For example, in the field of locomotion, one encounters stationary, legged, wheeled, swimming, and flying robots, as well as swarm robots, nanorobots, and soft robots.³⁰

Performance and Robotic

I was instinctively drawn to robots because I could make them move.³¹

Catie Cuan works as a dancer, and choreographer and is a PhD candidate in the Mechanical Engineering department at Stanford University. In her practice, she researches how humans and robots move together.³²

There are a lot of artists who contributed to the history of performing arts and robotics, like Nam June Paik, Jean Tinguely, Stelarc and Margo Apostolos, to name a few.³³ In the 1960s robotic artworks started to emerge. Eduardo Kac, a contemporary artist, claims three artworks

²⁸ DLR “LWR I (1991–1996)”. Accessed March 12, 2025, <https://www.dlr.de/en/rm/research/robotic-systems/arms/lwr-i-1991-1996>

²⁹ Northwestern University “Cobots: Robots for collaboration with people”. Accessed March 12, 2025, <http://peshkin.mech.northwestern.edu/cobot/>

³⁰ Frei P. „APPLIED CREATIVE ROBOTICS“ p.7

³¹ Cuan C. „Dances with Robots, Choreographing, Correcting, and Performing with Moving Machines“. p.125

³² Ibid. p.124

³³ Cuan C. et. al. „Breathless: An 8-hour Performance Contrasting Human and Robot Expressiveness“. p.2

that stand as landmarks in this field: *Robot K – 456* by Nam June Paik and Shuya Abe in 1964, Tom Shannon's *Squat* in 1966, and from 1969 – 1970 *The Senster* by Edward Ihnatowicz.³⁴

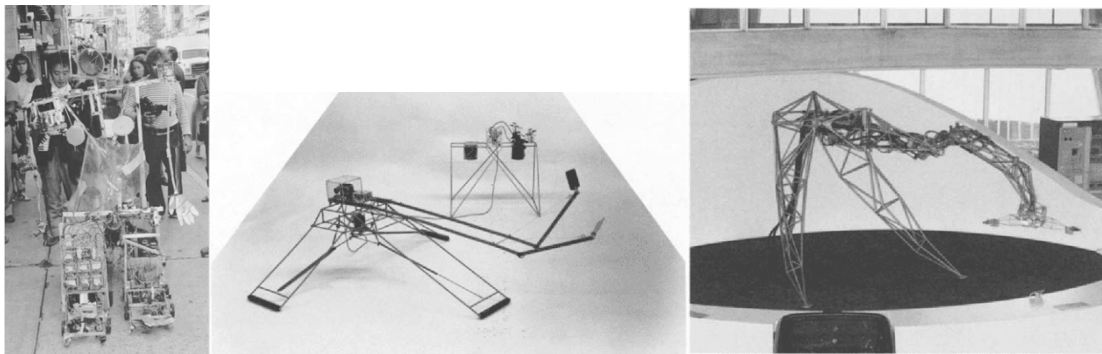


Figure 4: Three landmarks in robotic arts in the 1960s (left to right: *Robot K-456*, *Squat*, *The Senster*).
Last Accessed March 14, 2025, <https://www.semanticscholar.org/paper/Foundation-and-Development-of-Robotic-Art-Kac/cf51b9b9a86fd6e0b2881b3388a2694ba0645b63>

Back in 1997, Eduardo Kac stated that a core issue of creating robotic art is the very definition of it. Robots have a rich cultural history relating to mythological traditions of diverse cultures. In addition to these cultural narratives there is also the aspect of scientific research and its usage in industrial applications where robots are meant to fulfil a task or a set of tasks.³⁵

As artists continue to push the very limits of art, traditionally defined by discrete and inert handmade objects, they introduce robotics as a new medium at the same time that they challenge our understanding of robots-questioning therefore our premises in conceiving, building, and employing these electronic creatures.³⁶

Kac E. argues that artists are not able to ignore mythological, literary, or industrial definitions, but they are free to explore robotics in their own particular way. Still, in 2024 Catie Cuan emphasized the importance of contributions by artists, choreographers, theatre artists, and musicians for research in human-robot interaction.³⁷

Artistic References

Part of my artistic research was to collect other existing projects in the realm of robotics and performance art. The following examples demonstrate the state of the art and function as an inspiration to my concept.

³⁴ Kac Eduardo „Foundation and Development of Robotic Art“ p.61

³⁵ Kac Eduardo „Foundation and Development of Robotic Art“ p.60

³⁶ Ibid. p.60

³⁷ Cuan C. et. al. „Breathless: An 8-hour Performance Contrasting Human and Robot Expressiveness“. p.3

The Beach

The robotic performance *The Beach* created by Roy Nachum and VOLVOXLABS, is installed at the Mercer Labs in New York City since 2024. They are using an industrial robotic arm that is surrounded by sand and stands behind a glass wall to explore the human imagination. Through an eight-hour day performance the robot acts and interacts in a human-like manner.³⁸ It draws messages in the sand, cleans it up and moves in a certain pattern. During the performance is a very interesting moment when the robot arm comes so close to the glass wall that it can almost reach the visitor on the other side it. Visitors are separated from the installation by the glass, but there is a slim table to the left and right of the room with sand on top. This invites visitors to touch and mould the sand themselves, thus introducing a tactile sensation to the viewer that puts them in a similar situation as the robot arm. This concept was very influential during my artistic process.

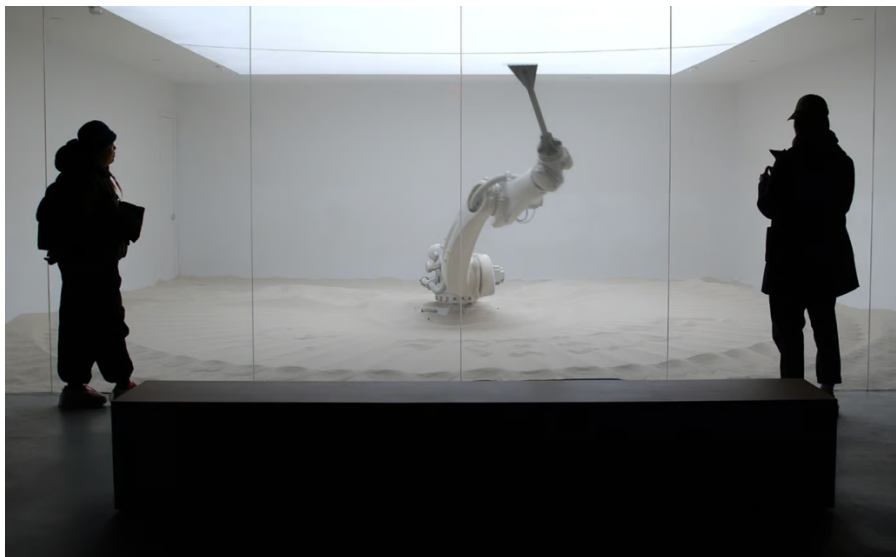


Figure 5: Picture of the Robotic Performance. *The Beach* by Roy Nachum and VOLVOXLABS, Mercer Labs New York City. Last Accessed February 21, 2025 <https://thevendry.com/events/44243/mercer-labs-the-beach-kuka-robot-arm-new-york/#f=666671>

Propel: Body on Robot Arm

Stelarc produced a performance called *Propel: Body on Robot Arm* and *Propel: Ear on Robot Arm*, which was realized at the company Autronics in the year 2015. For this piece, a 6-degree-of-freedom industrial robot arm was used to first lift Stelarc and later a life-size sculpture of his ear. The Choreography is done by the robot as the arm moves the body's trajectory, velocity and position/orientation in space. Stelarc says “The body and the robot become one interactive

³⁸ METALOCUS „The Beach“. Accessed February 21, 2025, <https://www.metalocus.es/en/news/beach-robotic-performance-roy-nachum-volvoxlabs>

and aesthetic operational and performing system.”³⁹ The performing KUKA arm, also carved the life-size ear, which was exchanged with the human body to repeat the choreography. The programming of the movement was done off-line and later transferred to the robot. For safety reasons there was one person on the kill switch during the performance in case the arm did something unexpected.⁴⁰

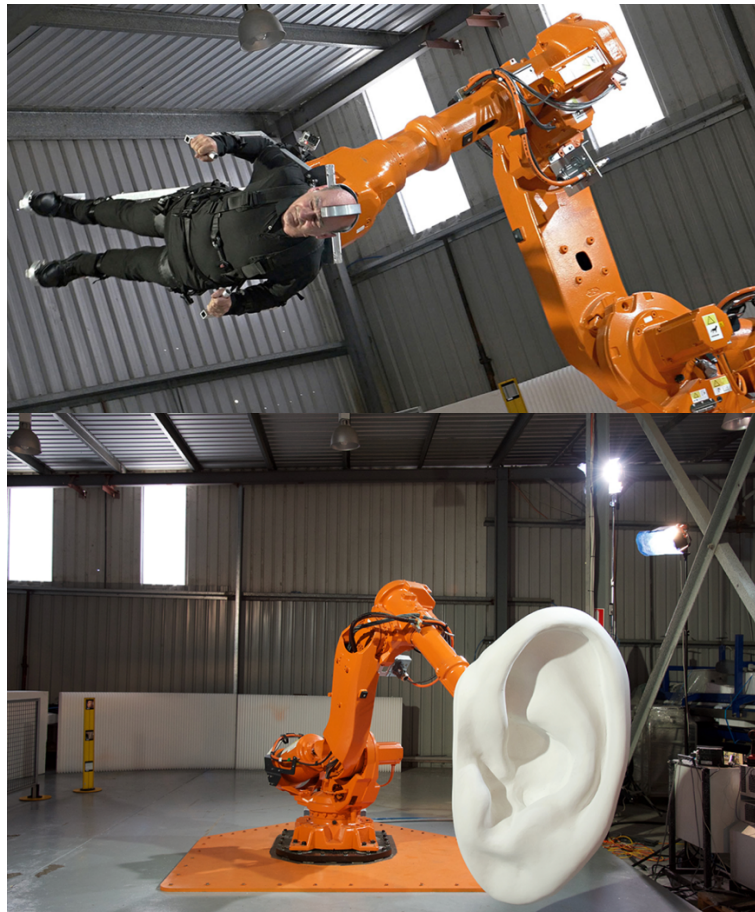


Figure 6: Documentation of the Performance at Autronics, *PROPEL: BODY ON ROBOT ARM* and *PROPEL: EAR ON ROBOT ARM* by Stelarc. Last Accessed February 21, 2025. <http://stelarc.org/activity-20354.php>

Körper

The dance theatre piece *Körper* by Sascha Waltz celebrated its premiere in 2000 and dealt with the most fundamental medium: the body. Waltz raises questions like: “What is the body? and how is it constructed?”⁴¹ In her piece, which was performed with thirteen dancers, she explored the body in all its parts and details. These details are portrayed in the 58-minute-long

³⁹ Stelarc “PROPEL: BODY ON ROBOT ARM” and “PROPEL: EAR ON ROBOT ARM”. Accessed February 21, 2025, <http://stelarc.org/activity-20354.php>

⁴⁰ Ibid.

⁴¹ Schaubühne „Körper“. Accessed February 21, 2025, <https://www.schaubuehne.de/de/produktionen/koerper.html>

performance, seemingly told in chapters. This inspired me to work with bodily sensations collected through movement experiments and translate them into chapters or a narrative. These so-called chapters/scores form the foundation for the choreography of my piece.



Figure 7: Video still of the Trailer. *Körper* by Sasha Waltz. Last Accessed February 21, 2025. <https://www.sashawaltz.de/en/gjbpr7oqrc#gndss198j>

The play also dealt with body language and questions whether body language often conveys more truth than the spoken word.⁴² Waltz implements a glass box for her scenography where in one section the dancers are inside, pressed together like reptiles in an aquarium without water.⁴³ It is another artistic reference, that uses a glass wall as a separation from the viewer or others.

Split Subject

Split Subject is an artistic research project developed in 2022 by Amir Bastan in cooperation with Qapture Gmbh, Silke Grabinger and Creative Robotics. The original idea was to create a meaningful connection between the audience and the robot. For this project, a quadruped robot called Spot by Boston Dynamics was used.⁴⁴ This robot can move freely in space and does not need to be mounted somewhere. One aim of this project was to combine performativity with robotics which was inspired by the performance piece *I Like America and America Liked Me*, performed by Josef Beuys in 1974 in New York.⁴⁵ Beuys spent three days in a room with a wild

⁴² Spiegel Kultur „Tanz die Leber“. Accessed February 21, 2025, <https://www.spiegel.de/kultur/gesellschaft/koerper-in-berlin-tanz-die-leber-a-712942.html>

⁴³ Ibid.

⁴⁴ Amir Bastan “Split Subject”. Accessed March 11, 2025, <https://amirbastan.com/projects/splitsubject/>

⁴⁵ Hamburger Kunsthalle “Joseph Beuys I like America and America likes me, 1974”. Accessed March 11, 2025, <https://online-sammlung.hamburger-kunsthalle.de/de/objekt/V-1992-04/i-like-america-and-america-likes-me?term=&start=62600&context=default&position=62615>

coyote and left the audience wondering about the potential interaction of the performer and the coyote. In comparison to *Split Subject* Amir Bastan claims, that the performance attempts to reproduce a situation, where the dancer and the robot are stuck in their current state.⁴⁶



Figure 8: Screenshot, Creative Robotics website, Documentation of the research project “Split Subject” 2022 by Amir Bastan Qapture Gmbh, Silke Grabinger and Creative Robotics. Last Accessed March 11, 2025
<https://creativerobotics.at/split-subject/>

Silke Grabinger later produced a different version of the piece in cooperation with Zirkus des Wissens and the Institute of Robotics at the Johannes Kepler University Linz and called it *SPOTSHOTBEUYS*.⁴⁷ Grabinger was part of other projects in the realm of performance and robotics like *Underbody* by Johannes Braumann, Amir Bastan, Anna Seyr and Karl Singline, in cooperation with the Ars Electronica Festival 2019.⁴⁸

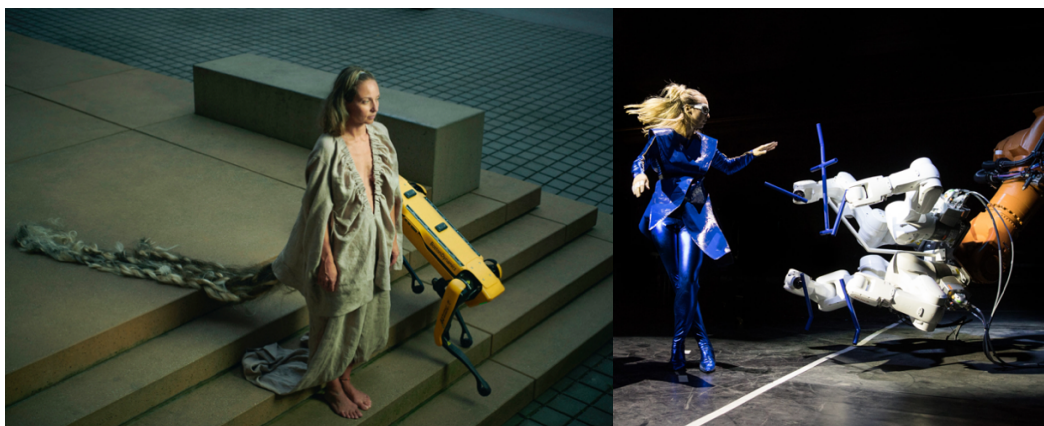


Figure 9: Screenshot Website Silke, Documentation of “SPOTSHOTBEUYS” 2024. Last Accessed March 11, 2025.
<https://www.silk.at/repertory/spotshotbeuys> (left image)
 Screenshot Website Creative Robotics, Documentation of “Underbody” 2019. Last Accessed March 11, 2025.
<https://creativerobotics.at/underbody/> (right image)

⁴⁶ Amir Bastan “Split Subject”. Accessed March 11, 2025, <https://amirbastan.com/projects/splitsubject/>

⁴⁷ Silk “SPOTSHOTBEUYS”. Accessed March 11, 2025, <https://www.silk.at/repertory/spotshotbeuys>

⁴⁸ Creative Robotics „Underbody“. Accessed May 11, 2025 <https://creativerobotics.at/underbody/>

Experiment

To explore the bodily responses of humans while moving with robots, I created an experimental set-up, where participants had to perform three different tasks with a robotic arm. While performing each of these tasks the body movement of the participants and the movement of the arm were recorded.

I first moved with robots myself to get an impression of what kind of bodily sensations I have in order to come up with suitable tasks. In the picture below I am playing a game designed by Amir Bastan using two Kuka robotic arms. The goal of the game is to move a ball, controllable by the robotic arms, through a parkour to a finish point. I am fascinated by robots and how we can connect with them so, I was not afraid to touch them and play around. In the beginning, it felt unfamiliar to move with two arms, that were quite similar in size to me. However, the arms moved smoothly and were not that heavy. The trickiest part was to use them as controllers as the movement of the ball in the game was quite sensitive to what you did with the robots. The longer I played the better I got and after a while, I even forgot that I was co-playing with two robotic agents. What I took away from this, is that in the beginning, people will probably be very focused to do nothing wrong and get used to the feeling of moving the robotic arms. Therefore, the first task should be an introduction and a warm-up to the next steps. Afterwards, something more complex can follow, which is open to individual creativity as well.



*Figure 10: Playing with two robotic arms in the Creative Robotic Lab, Linz.
Picture taken by Amir Bastan February 13, 2025.*

The following tasks were performed by eleven people, five of whom had a dance background.

TASK 1:

Examine the possibilities of the robotic movement: try to move it carefully as fast and then as slow as you can.

TASK 2:

Behave like the robot arm is your dance partner and you must guide the robot through a choreography containing the following elements. (stay in physical contact)

rotation

close to your body

the furthest distance from your body

TASK 3:

Imagine you are meeting a person (someone you like or dislike) and you want to tell them through movement, how you feel about them.

Experimental Design

Each task had a different objective but were formed in such a way that the tasks increased in emotionality. The first round was about exploring the possible movements of the robotic arm, especially the fact, that to release and move the arm, a button must be constantly pressed. In the questionnaire given to the people afterwards, they stated that it was unfamiliar and draining to keep the button pushed. Furthermore, the robot is in some ways limited in its movement. 45,5 % of the respondents would like to change the reactivity and the rotation of the robotic movement. It was important to me that the participants get used to these limitations before the tasks got more extensive and emotional.

In the second task, the participants should pretend that the robot arm is their dance partner. This was the next stage in the experiment, since it was still about finding out how to dance with the robot, but with purpose in the movements. One of the performers was surprised that it reminded them of leading another person in dance, as they felt like the robot had a similar kind of resistance to their input.

The last assignment was the most emotional one. To start actors were asked to imagine and decide whether the robot is someone they liked or disliked. The idea behind this decision making was to generate an emotion in the person performing with the robot. In the next step the performers were asked to express their feelings through movement so as to see how the participants embody their feelings. The following statement of a participant demonstrates the effect this had on them:

I was surprised how much my feeling of power changed when I chose to have the robot be someone I dislike. I think I'm a little scared of robots in general and the thought of "they have their own brain" or "they will overtake our lives" and that 3rd task put a different lens on that thought.

Set-Up

In this room (*see Figure 11*) the tasks were performed the LBR iisy Cobot placed in the center. A lightweight robotic arm by the company KUKA. Each of the eleven participants got up to five minutes per task. However, each performer was free to choose when they have finished a task, except if they have reached the five minutes, I stopped them. Several cameras were placed in the room to track the body and robotic movements. Besides the cameras, we used the software VVVV, to control and record the robot and revisit the movement material afterwards.



*Figure 11: Picture of the room used for the experimental set-up.
Picture taken by Theresa Hajek February 13, 2025.*

Software

VVVV is a visual live-programming environment⁴⁹ and was used to build the interface of the experiment. To record gestures and poses the VL.MediaPipe nuget was installed and data was extracted.⁵⁰ Figure 12 and 13 show parts of the patch, that was used after the artistic experiment to filter the pose and gesture positions from the recorded videos of the people performing the tasks.

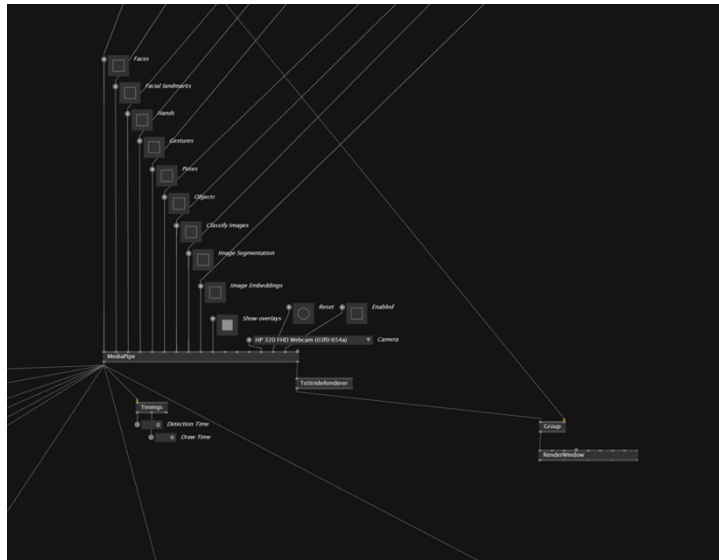


Figure 12: Screenshot of the project patch, showing the VL.MediaPipe.
Picture taken by Theresa Hajek March 15, 2025.

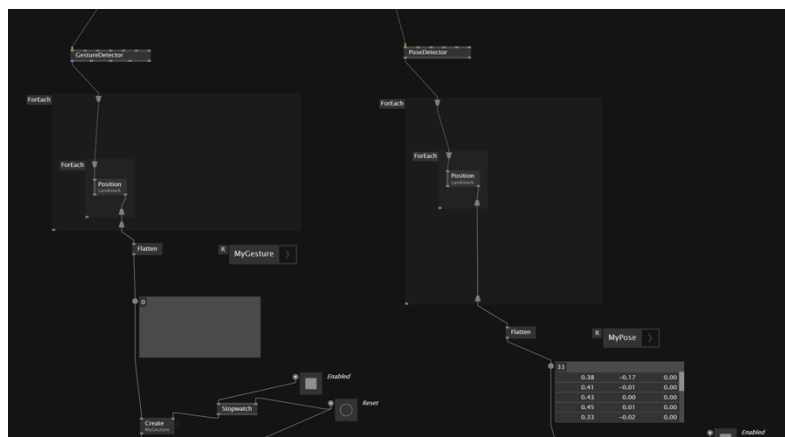


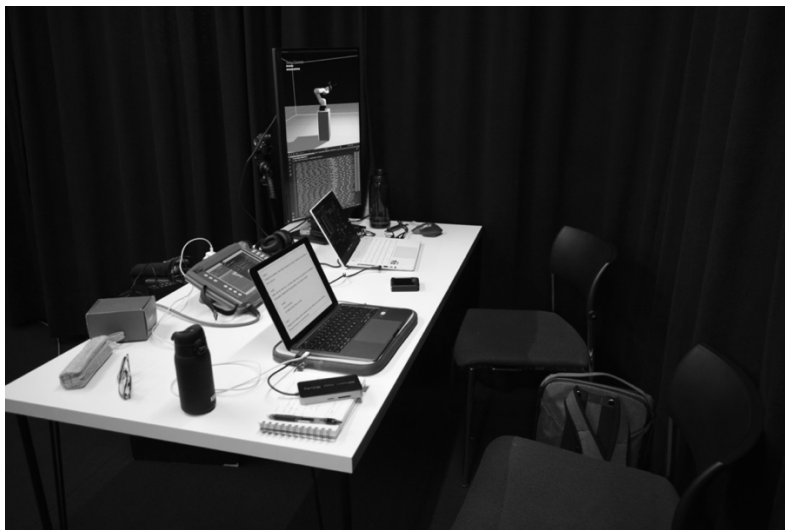
Figure 13: Screenshot of the project patch, showing the nodes of gesture and pose.
Picture taken by Theresa Hajek March 15, 2025.

In the room where the test series was carried out, we set up a table (see Figure 14) where Amir and I sat to document the process. Amir was responsible for recording the data of the robot, and I explained the tasks and coordinated the camera recordings. The LBR iisy Cobot was placed

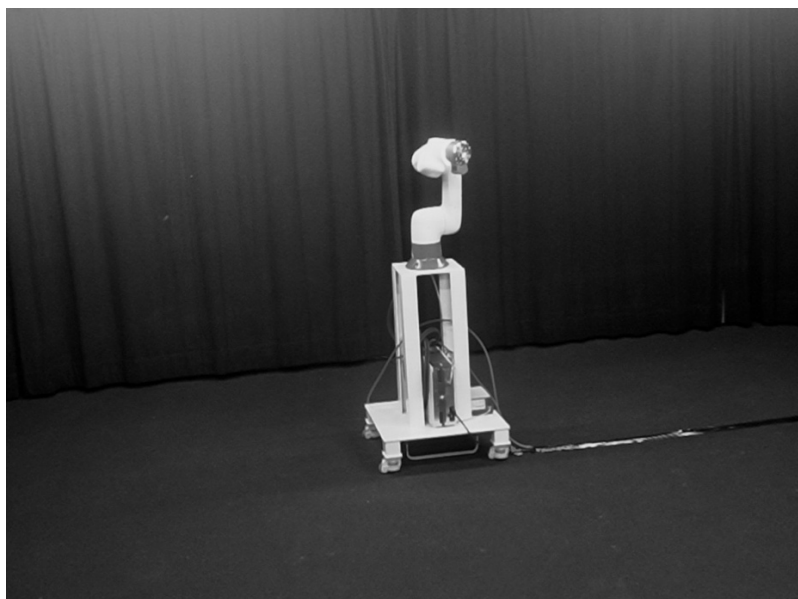
⁴⁹ Website „VVVV“. Accessed March 16, 2025. <https://vovv.org>

⁵⁰ Nuget „VL.MediaPipe“. Accessed March 16, 2025. <https://www.nuget.org/packages/VL.MediaPipe>

in front of the table to give a good overview of the performed movements (*see Figure 15*). On April 01, 2025, the artistic experiment was executed and completed within one day. The experiment was conducted as follows: participants were divided into two groups (morning and afternoon). Each group was asked to go to a waiting room where they filled out the first questionnaire. Then I asked each person individually to come into the room with the robot where I explained what was going to happen and what rules were to be followed then the participant was given the first task. When the exercise was completed, I explained the next one. After the third task was completed, the performers returned to the waiting room to fill out the second questionnaire and the body sensation mapping.



*Figure 14: Set up to record the experiments.
Picture taken by Theresa Hajek April 01, 2025.*



*Figure 15: LBR iiy Cobot installed in the room.
Picture taken by Theresa Hajek April 01, 2025.*

Technical Aspects

There are many different types of robots such as industrial robots, service robots and medical robots; however, in my master project, I am focusing on collaboration. This means robots and humans are working and moving safely in the same space rather than to a traditional industrial robot where a physical safeguard is required, as they can cause injuries through collisions.⁵¹ To be more specific for my experimental set-up I used a robotic arm called LBR iisy Cobot by the company KUKA. This arm is intuitive to operate and reliable in contact with humans, which makes it a great technology to collaborate with. It has a low weight and can move at high speed, which makes it easy to handle.⁵² LBR iisy 3 R760 has sensors ensuring that performers can move safely and interactively in close proximity to it.



Figure 16: LBR iisy 3 R760 Cobot.

Accessed March 16, 2025. <https://www.kuka.com/en-at/products/robotics-systems/industrial-robots/lbr-iisy-cobot>

Although it can be assured that the performers will not be injured, there is a possibility that the robot could be damaged, so I explained the risks involved in handling the cobot accordingly. The most important instructions were not to put too much weight on the robot to not push it against anything and to move the arm only when the safety button is pressed and the movement is released.

⁵¹ Kuka “Cobots: Your entry into automation with collaborative robots”. Accessed February 25, 2025, <https://www.kuka.com/en-at/future-production/human-robot-collaboration/cobots>

⁵² Kuka „LBR iisy Cobot“. Accessed February 25, 2025, <https://www.kuka.com/en-at/products/robotics-systems/industrial-robots/lbr-iisy-cobot>

Experimental Outcome

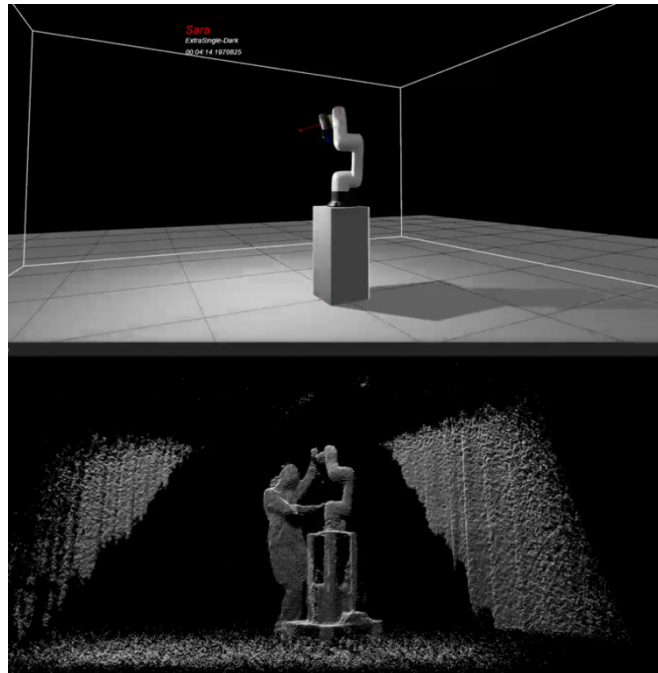
Through various applications such as questionnaires, BMS and recordings, a wide range of material and feedback could be collected. *Figure 17* shows one of the participants performing the task three.



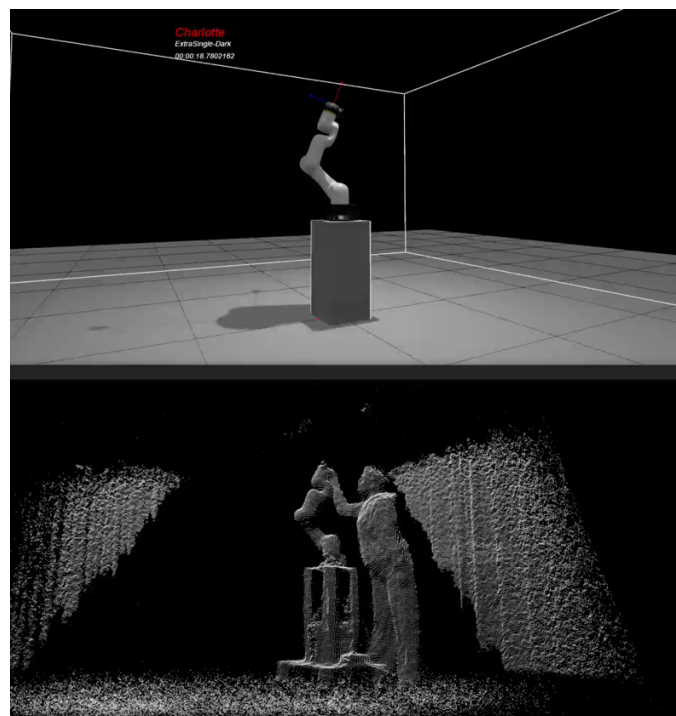
*Figure 17: Documentation of the experiment.
Picture taken by Theresa Hajek April 01, 2025.*

Movement Tracking

Each person and the cobot was recorded while performing so the movement of the robot and the person could be revisited. To record the movement data of the robotic arm, the software VVVV was used. A video still of the renderer window can be seen in *Figure 18 and 19*. Underneath the animation of the Cobot an image taken by a Kinect shows the set-up and the performer.



*Figure 18: Movement recording with VVVV and Kinect
Screenshot taken by Amir Bastan April 01, 2025.*



*Figure 19: Movement recording with VVVV and Kinect
Screenshot taken by Amir Bastan April 01, 2025.*

Personal Feedback

By using body sensation mapping and a questionnaire, I collected feedback from the participants. I asked the eleven people to fill out a questionnaire before and another after performing the tasks. The questions aimed to get a response from the candidates of what they

expected to happen, and how they felt. A tool to gather information about one's own body sensation is called body sensation mapping, in short BSM. BSM is a self-report instrument that uses a sheet with a human silhouette on it one can paint their bodily sensations onto the silhouette with colours, noting what has been experienced.⁵³ The core idea of the experimental approach was to gather information from each performer via BSM. So, after performing the tasks they were asked to paint their sensations on a sheet, to document what they felt during the robot interaction. It is important to emphasize that the participants only learned that they are asked to draw their body sensations after they have completed the tasks. The thought behind that was to ensure that the answers were intuitive. I did not want the performers to be biased or constantly thinking about how they feel during the movement exercises. Another crucial factor was that no one was allowed to share their experience unless everyone had completed the BSM and questionnaires to establish that it is an individual experience.

Body Sensation Mapping

Pain, pleasure, warmth and tickling serve as instances of bodily sensations. Feelings or sensory experiences that arise within the body can be a form of awareness or the perception of the external world.⁵⁴ The following illustrations are an example of how the self-reporting tool was executed. Everyone received an empty sheet (*see Figure 20*) and a list of words (e.g.: tense, touched, shaky, fluid etc.) as an inspiration. Participants chose the words to describe the sensations they felt. By assigning a colour to the word and drawing with the according colour on the silhouette, it was possible to trace which sensation occurred in which part of the body. (*see Figures 21-24*)

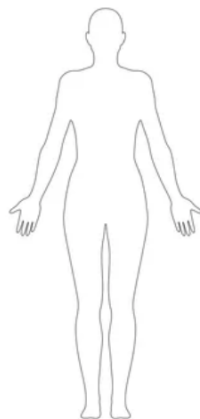


Figure 20: Example of an empty body silhouette sheet. Accessed March 16, 2025.
https://stock.adobe.com/at/search?k=human+body+outline&search_type=recentsearch&asset_id=306057154

⁵³ García-Magariño I. et al. „Bodily sensation maps: Exploring a new direction for detecting emotions from user self-reported data“ p.5

⁵⁴ Routledge Encyclopedia of Philosophy „Bodily sensations“. Accessed May 11, 2025.
<https://www.rep.routledge.com/articles/thematic/bodily-sensations/v-1>

These are four examples of how people mapped their sensations after fulfilling the tasks.

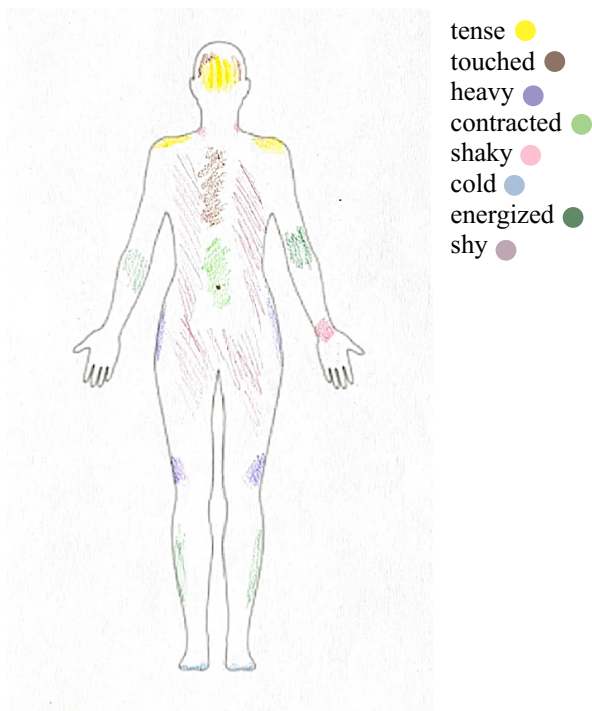


Figure 21: Participant 01, BMS

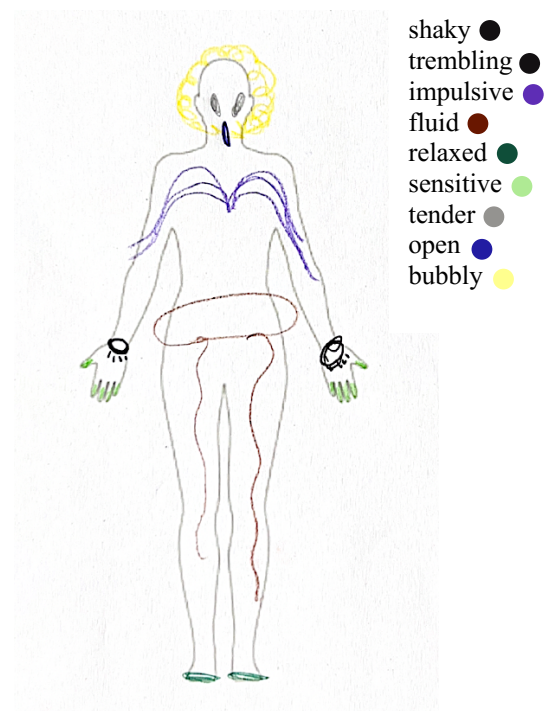


Figure 22: Participant 02, BMS

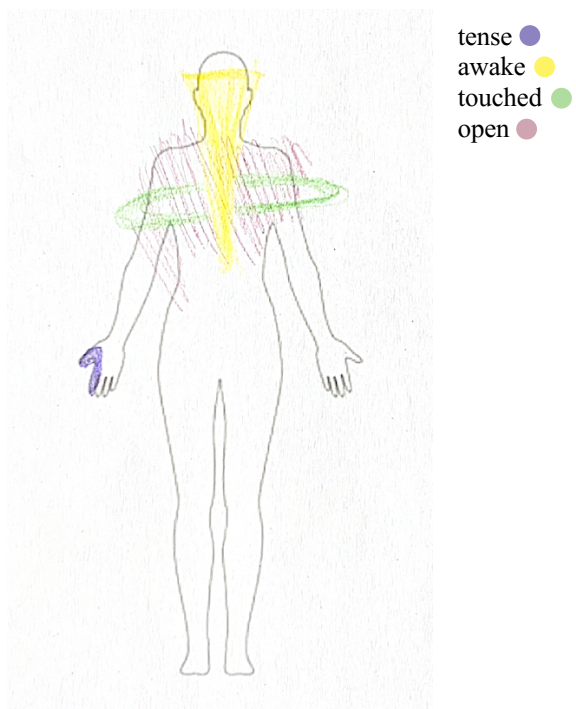


Figure 23: Participant 03, BMS

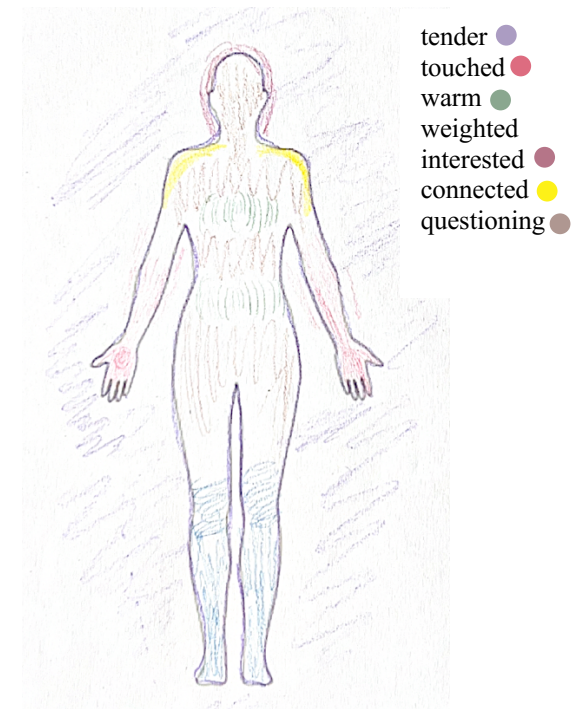
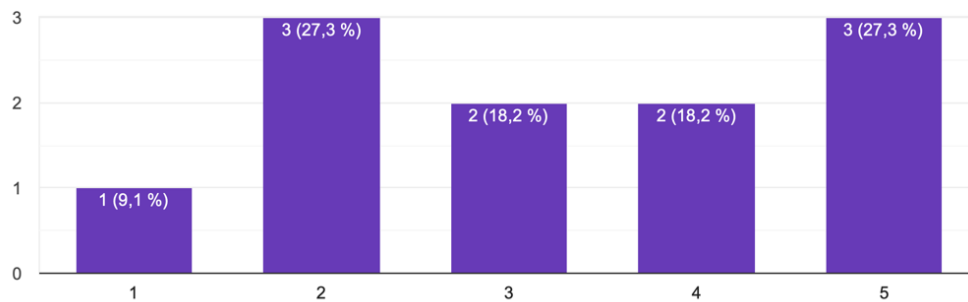


Figure 24: Participant 04, BMS

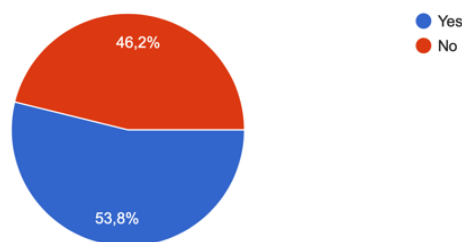
Responses

Additionally, to the body sensation mapping and the movement tracking I created two questionnaires to gather feedback from the participants. The first one was filled out before performing the tasks and the second one after. The questionnaires functioned as a tool to gain a better understanding for the bodily sensations reported by the performers.

The result of the question “How was it for you to move the robot?” indicates that I had a wide range of sensations. The *Figure 25* shows a scale from one, being unfamiliar, to five, being familiar, displaying the spread range of responses. Even though 53,8% have engaged with a robot before (*see Figure 26*) the experience of the movement was diverse.



*Figure 25: Responses to the question “How was it for you to move the robot?” (1 = unfamiliar, 5 familiar).
Figure by Theresa Hajek, April 02, 2025.*



*Figure 26: Responses to the question “Have you engaged with a robot before”.
Figure by Theresa Hajek, April 02, 2025.*

I was curious if people would like to change certain aspects of the robot's movement. As mentioned before to move the robotic arm, one must press the security button to release it. The answers showed that some did not feel comfortable to constantly press the button. Another aspect was that half of the group was not stratified by the rotation and felt limited by it (see Figure 27).

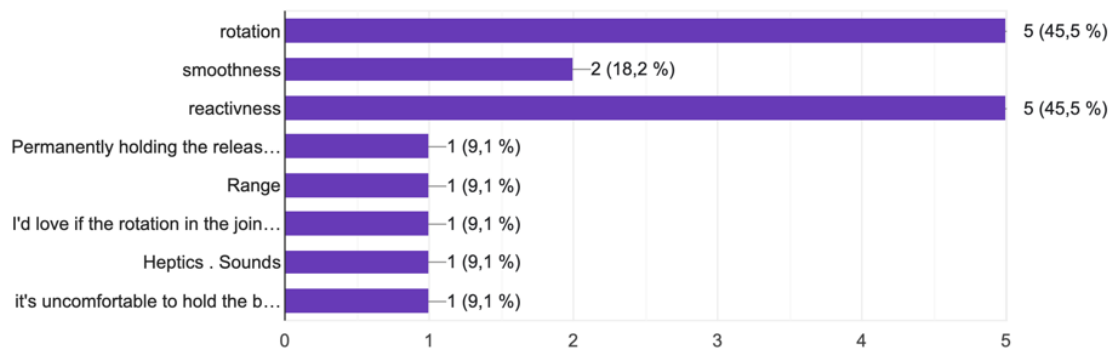


Figure 27: Responses to the question "Would you change something about how the robot moves?".
Figure by Theresa Hajek, April 02, 2025.

Figure 28 illustrates that for nine people something unexpected happened during their movement tasks. Only for two performers nothing was surprising

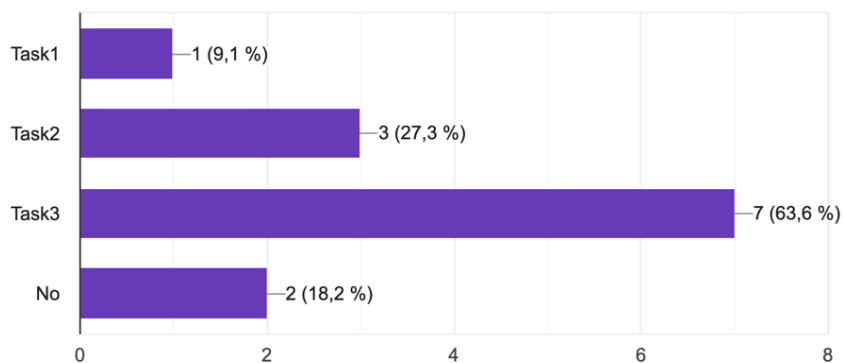


Figure 28: Responses to the question "Did something happen, that you did not expect?".
Figure by Theresa Hajek, April 02, 2025.

Anonymous answers from the participants regarding the question of whether something surprising happened.

Task 3: As an untrained puppeteer I memorize shifts from consciously animating the robots and my body to fully focusing on the robot's motion expression resulting with my body motion being a byproduct.

Task 3: I was surprised how much my feeling of power changed when I chose to have the robot be someone I dislike. I think I'm a little scared of robots in general and the thought of "they have their own brain" or "they will overtake our lives" and that 3rd task put a different lens on that thought.

Task 2: It very much reminded me of dancing/leading another person in dance, which I didn't expect because you don't expect the robot to have a similar kind of resistance to your input.

General: This size of robot is somehow similar to my arm size so it boosts a sense of replicating for me.

General: There were some disturbances, sometimes the robot did not turn to orange (waiting mode) but instead to red and rationally I know that it probably was a malfunction, but it felt a bit like really communicating and the robot interacting with me as if it was also sure it had a say in how to participate. Found that very fair!

Task 3: Both the task of liking or disliking this entity and the fact that I was able to.

General: It was surprising how I felt kind of intimate with the robot very quickly, I was not expecting that, as I came in robot-suspicious.

The following questions had the goal to collect feedback that went beyond the tasks. In my opinion the various anonymous responses show that people had very personal experiences.

How would you imagine a companionship with a robot?

Complicated

Companionship? I imagine it similar to having an imaginary friend. Something to project your feelings onto.

Very weird. It is an un-alive object, which tries to behave like a living thing or person, and that makes me feel uncomfortable.

What do you think, did the robot feel?

Suspicion.

I felt like it enjoyed it most of the time, except two instances where it just stopped.

I think it was nervous too.

Movement Score

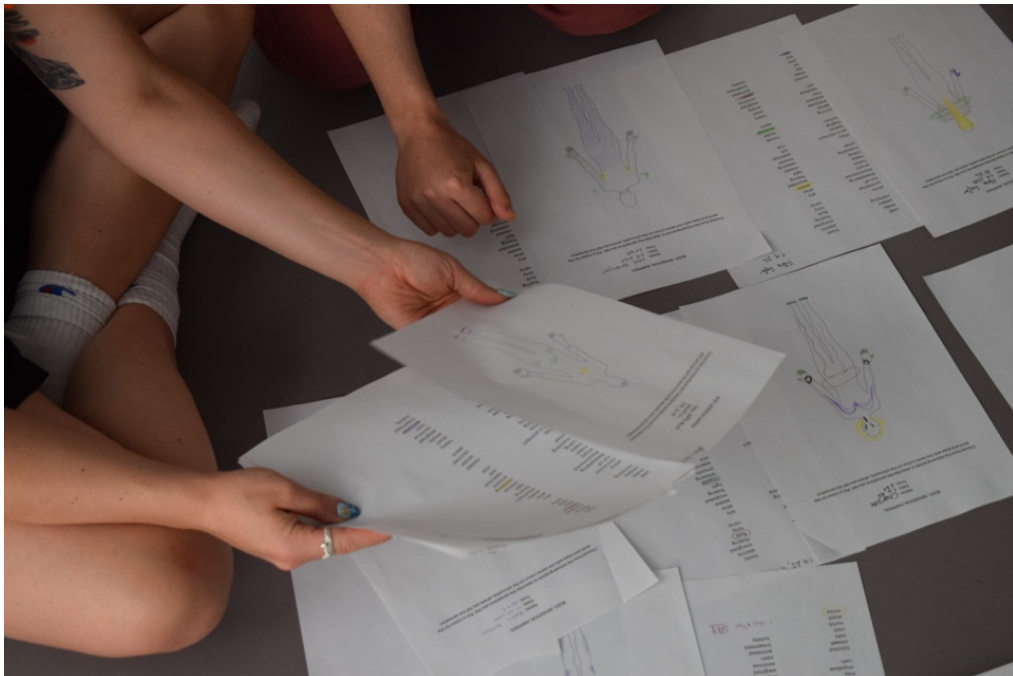
After evaluating the body sensation maps, the body sensations were translated into movement scores. Together with the two dancers Charlotte Safar and Sara Heitzinger, this final step of the project was developed.



Figure 29: Charlotte Safar (left) and Sara Heitzinger (right) while exploring movement possibilities with the LBR iisy.
Picture taken by Theresa Hajek, April 01, 2025.

The movement score worked as follows: for example, if a person said that they felt blocked in their chest while moving with the robot this sensation was translated into the movement – such as *using your whole body, tensing it and moving in a blocked way* forming one score. Out of all the sensations that have been selected, a set of scores was generated. This score was used to build a choreography.

Charlotte Safar, Sara Heitzinger and I went through all body sensation maps in our first rehearsal. Collaboratively we filtered what kind of sensations appeared more frequently and which seemed to be in contrast. *Touched, tender* and *shy* were put in one category, while *weighted* and *shaky* felt like they belonged in contrast to those. In the next step the two dancers embodied the selected sensations into a movement score. I took on the role of an observer and gave them feedback after each sequence. Together we realized that these sets of movements were highly emotionally loaded, which led us to the decision of creating a point of release by portraying sensations like *fluid, warm* and *open*, which were mentioned often. Going through the body sensation maps I realized that participants felt either static or active only a few felt a mixture.



*Figure 30: Collaboratively evaluating the body sensation maps of the participants.
Pictures taken by Flora Safar, May 02, 2025.*

Critical Reflection

The experimental approach of my project proved effective, and a lot of information was gathered. I was fortunate to work with a diverse group of collaborators and participants, which enriched the outcome of the project. The tasks seemed clear and understandable and could be completed within the given time frame. It would be interesting to do the same experiment with more people to find out if certain bodily sensations repeat. With eleven participants this cannot be evaluated but can be observed subjectively. Furthermore, throughout the series of experiments, the human was always in the position of guiding the robot through the movements. In future trials it would be interesting to see if a robot moving independently might trigger other body sensations in the human. One element that could not be excluded is the aspect of how the robot looks and how it is built. In my experiment, I was not interested in the appearance's influence on the participants' experience. However, I cannot completely rule out that the visual design had a certain effect. To pinpoint how exactly the motion design affects the body sensations of those interacting with it, repeating the experiment with different robots in the future would bring significant new input. Additional trials also bear the potential of generating further movement scores based on the robot.

The notion and impact on humans of robot-like behaviour has existed for centuries and is culturally loaded relating to mythological traditions, philosophy and literature of diverse cultures.⁵⁵ Human-robot interaction is a research field that is multidisciplinary in its core.⁵⁶ In my project I am aiming to include the discipline dance in the research. As motion design in HRI is fixated on anthropomorphic- or imitation-based concepts, such as speed and efficiency, dance would allow to go beyond those parameters.⁵⁷ Dance was chosen as a medium to translate bodily sensations into bodily expressions. The individual experience of moving with robots was transferred into a performative process that can be perceived by an audience.

⁵⁵ Kac Eduardo „Foundation and Development of Robotic Art“ p.61

⁵⁶ Goodrich M. A. and Schultz A. C. „Human-Robot Interaction: A Survey" p.211

⁵⁷ Maguire-Rosier K. et.al. „What Other Movement Is There? Rethinking Human-Robot Interaction through the Lens of Dance Performance“ p.90

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Affidavit

I hereby declare that I am the sole author of this work. No assistant other than which is permitted has been used. Ideas, concepts and quotes taken directly or indirectly from other sources are identified as such.

Vienna, May 11, 2025.

A handwritten signature in black ink, appearing to read 'Hajek T.' with a stylized flourish.

Theresa Hajek