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Santa Clara University

Interactive Assistive Robots for Persons with Impairments

Maria Kyrarini

Assistant Professor and David Packard Jr. Faculty Fellow

Department of Electrical and Computer Engineering

Santa Clara University

mkyrarini@scu.edu

11.14.2023

About me

- 2012: **Dipl. Eng.** in Electrical and Computer Engineering, National Technical University of Athens, Greece
- 2014: **M.Sc.** in Automation Systems, National Technical University of Athens, Greece
- 2013-2014: Erasmus Scholarship at Institute of Automation, University of Bremen, Germany

EU FP7 project CORBYS

(Cognitive Control Framework for Robotic Systems)

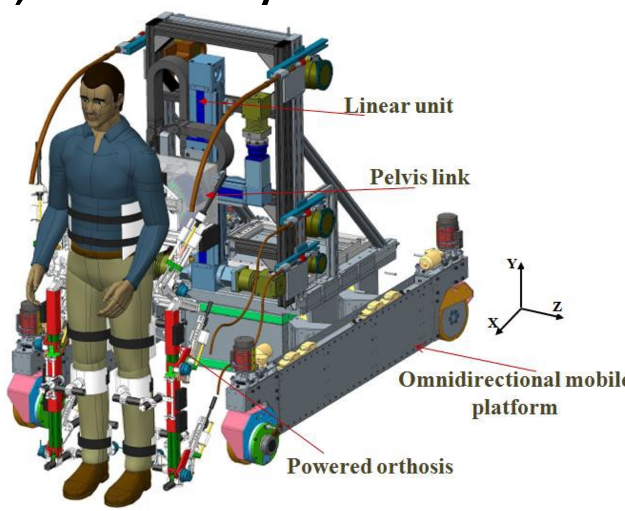

Image source: Kyrarini, M., Slavnić, S. and Ristić-Durrant, D., 2014. Fuzzy controller for the control of the mobile platform of the CORBYS robotic gait rehabilitation system. *Facta Universitatis, Series: Mechanical Engineering*, 12(3), pp.223-234.

About me

- 2015-2019: **Dr. Eng.** in Electrical Engineering, University of Bremen, Germany, under the supervision of **Prof. Dr.-Eng. Axel Gräser**

MeRoSy

MobiLe

- 2019-2021: **Postdoctoral Research Fellow** and **Assistant Lab Director** at Heracleia Lab, Department of Computer Science and Engineering, University of Texas at Arlington, under the supervision of **Prof. Dr. Fillia Makedon**

About me

- 2021-present: **Assistant Professor and David Packard Jr. Faculty Fellow,** Department of Electrical and Computer Engineering, Santa Clara University

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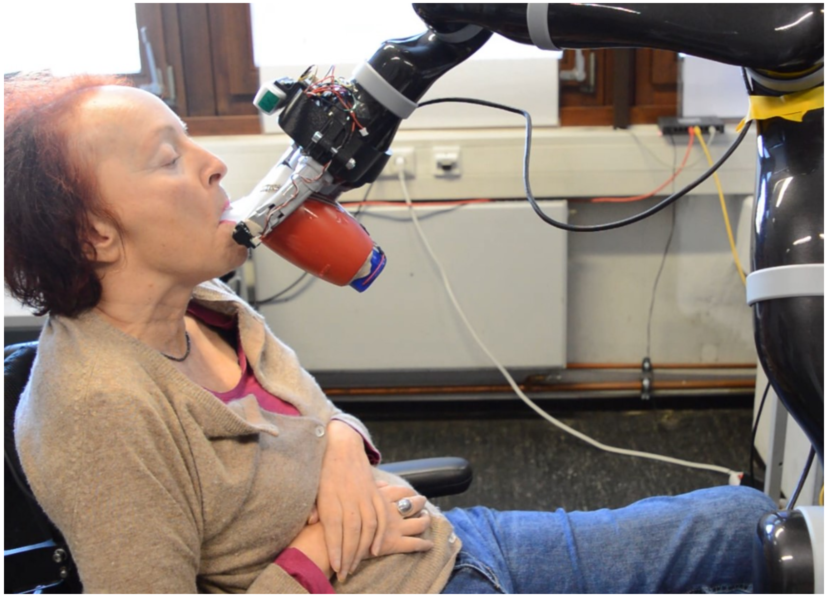
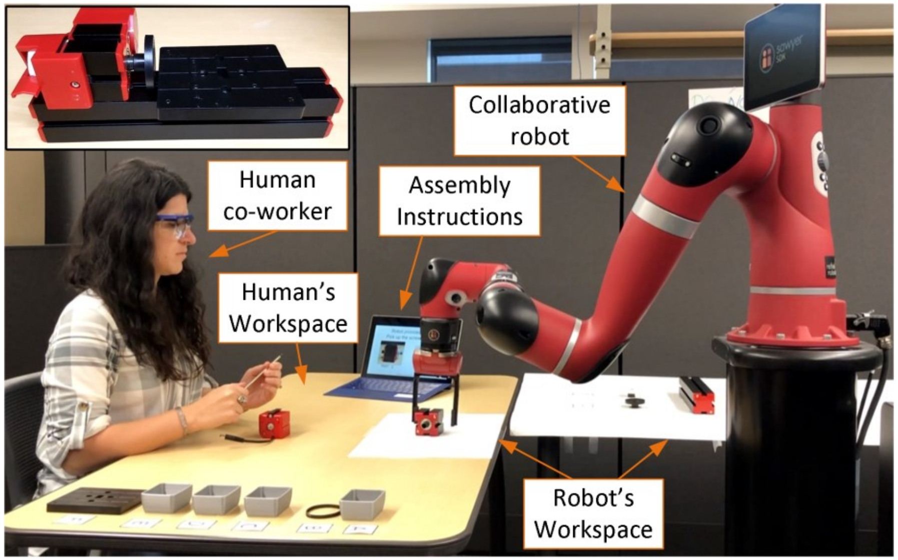
Santa Clara University
School of Engineering

ENGINEERING WITH A MISSION

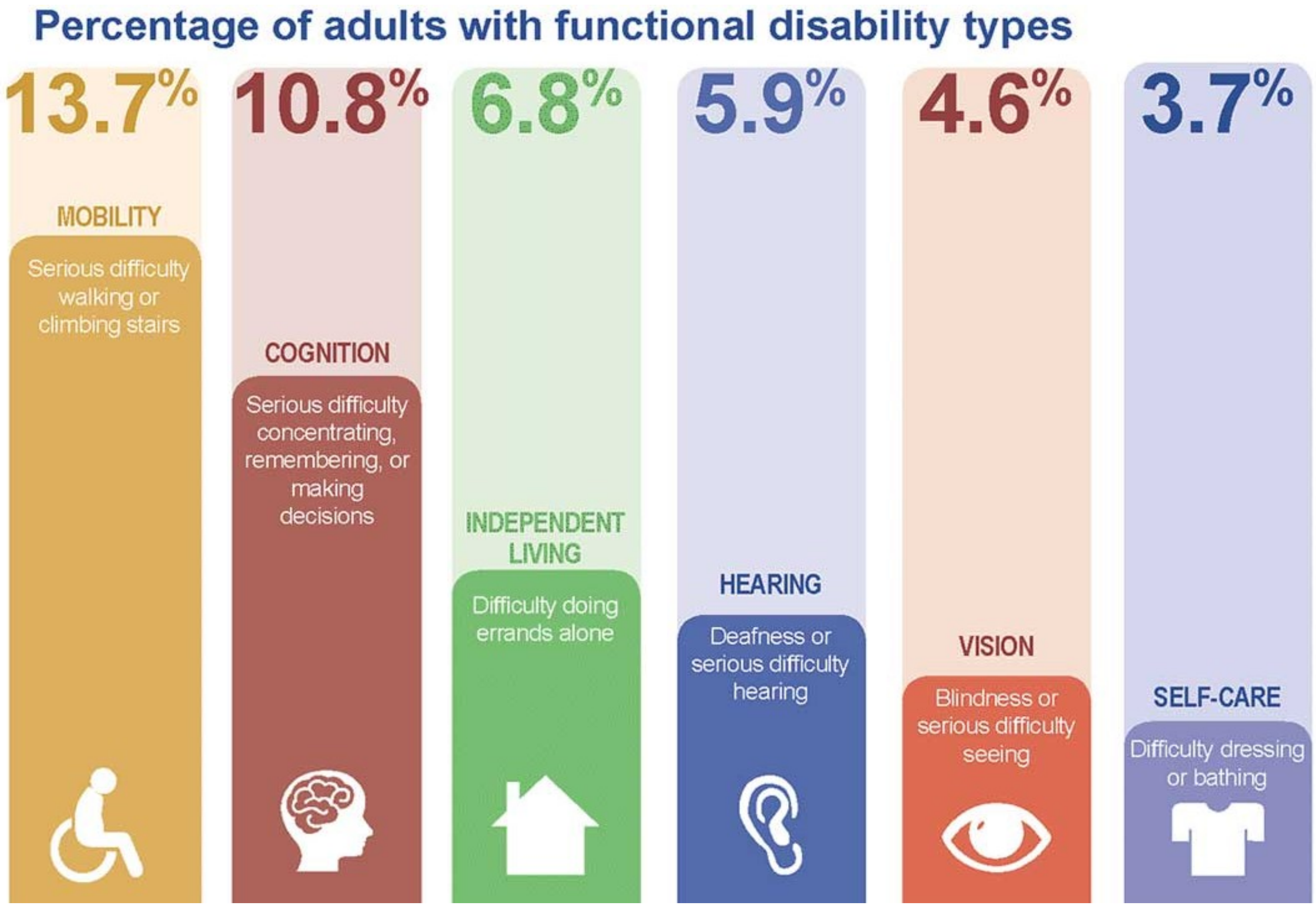
Outline




Collaborative robot
Human co-worker
Assembly Instructions
Human's Workspace
Robot's Workspace

Introduction

- 1 in 4 of adults in the US have some type of disability.

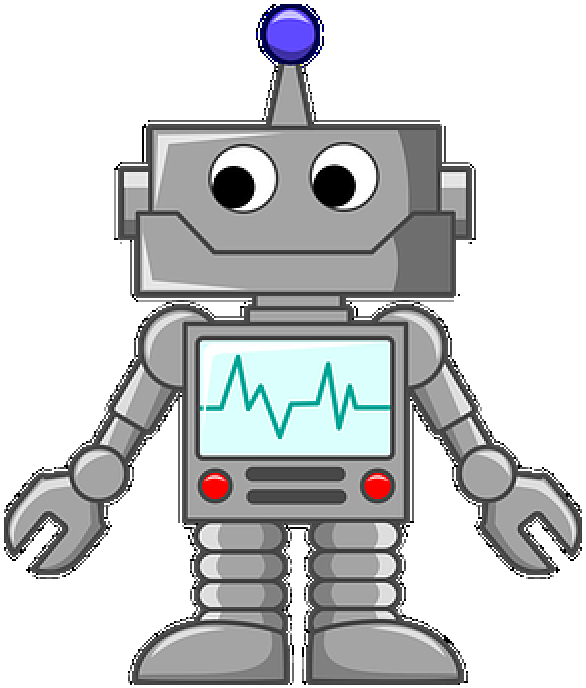


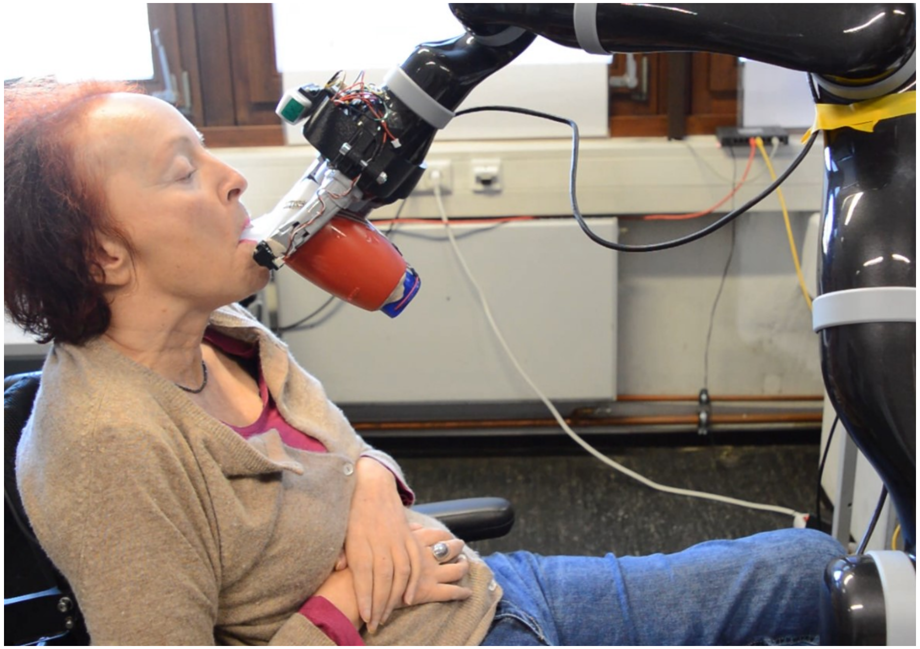
Source: https://abilitymagazine.com/61-million-people-with-disabilities-in-the-united-states/

Introduction

- **Paralysis:** the loss of the ability to move some or all of your body.
- **Tetraplegia** (Quadriplegia): paralysis of all 4 limbs + the torso.

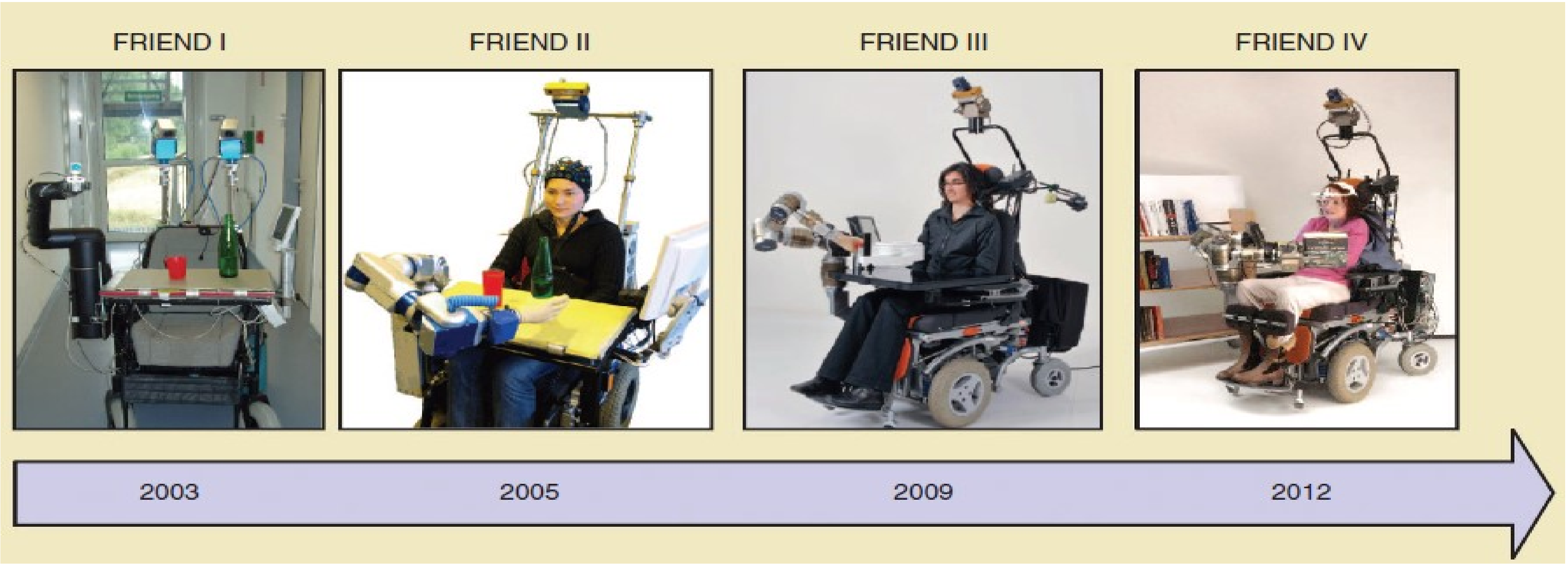
Motivation





Goldau F.F., Shastha, T.K., Kyrarini M., Gräser A., 2019. Autonomous Multi-Sensory Robotic Assistant for a Drinking Task. In *2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR).*

Motivation



Graser, A., Heyer, T., Fotoohi, L., Lange, U., Kampe, H., Enjarini, B., Heyer, S., Fragkopoulos, C. and Ristic-Durrant, D., 2013. A supportive friend at work: Robotic workplace assistance for the disabled. *IEEE Robotics & Automation Magazine, 20(4),* pp.148-159.

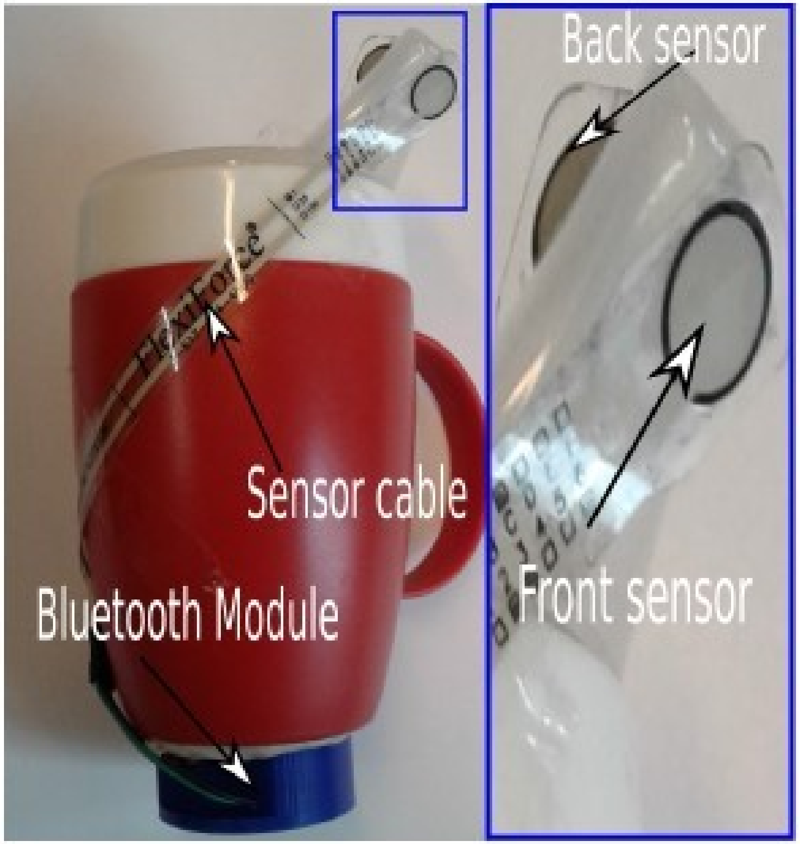
Semi-Autonomous Robotic Assistant

- Drinking without a straw
- Human in the Loop
- Intuitive and easy to use
- Safe approach and drinking activity

Goldau F.F., Shastha, T.K., Kyrarini M., Gräser A., 2019. Autonomous Multi-Sensory Robotic Assistant for a Drinking Task. In *2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR).*

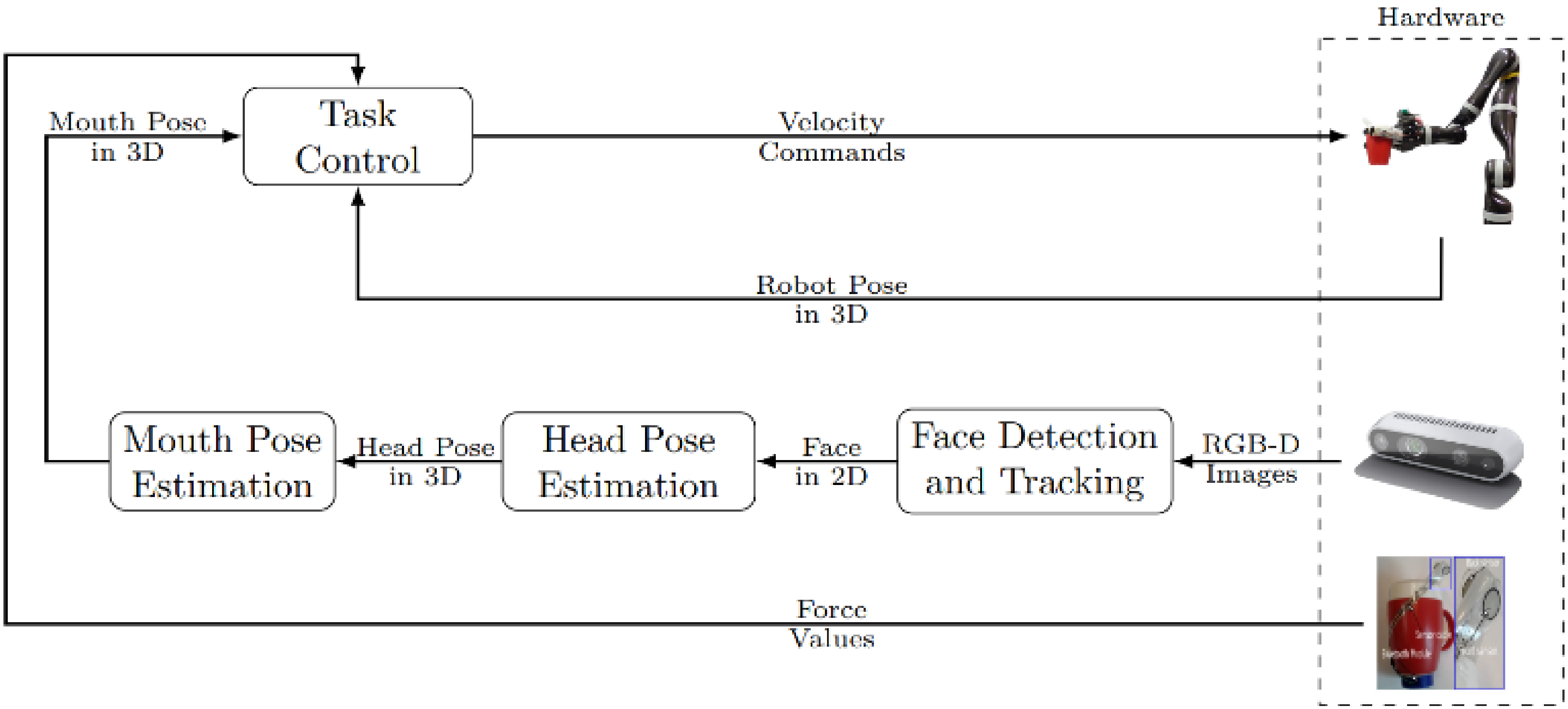
Semi-Autonomous Robotic Assistant

- Vision-based control to approach the user and serve the drink
- Force-based control for the drinking process



Koller T.L., Kyrarini M., Gräser A., 2019. Towards robotic drinking assistance: Low cost multi-sensor system to limit forces in Human-Robot-Interaction. In *12th ACM International Conference on PErvasive Technologies Related to Assistive Environments.*

Vision-based Robot Control to Serve a Drink



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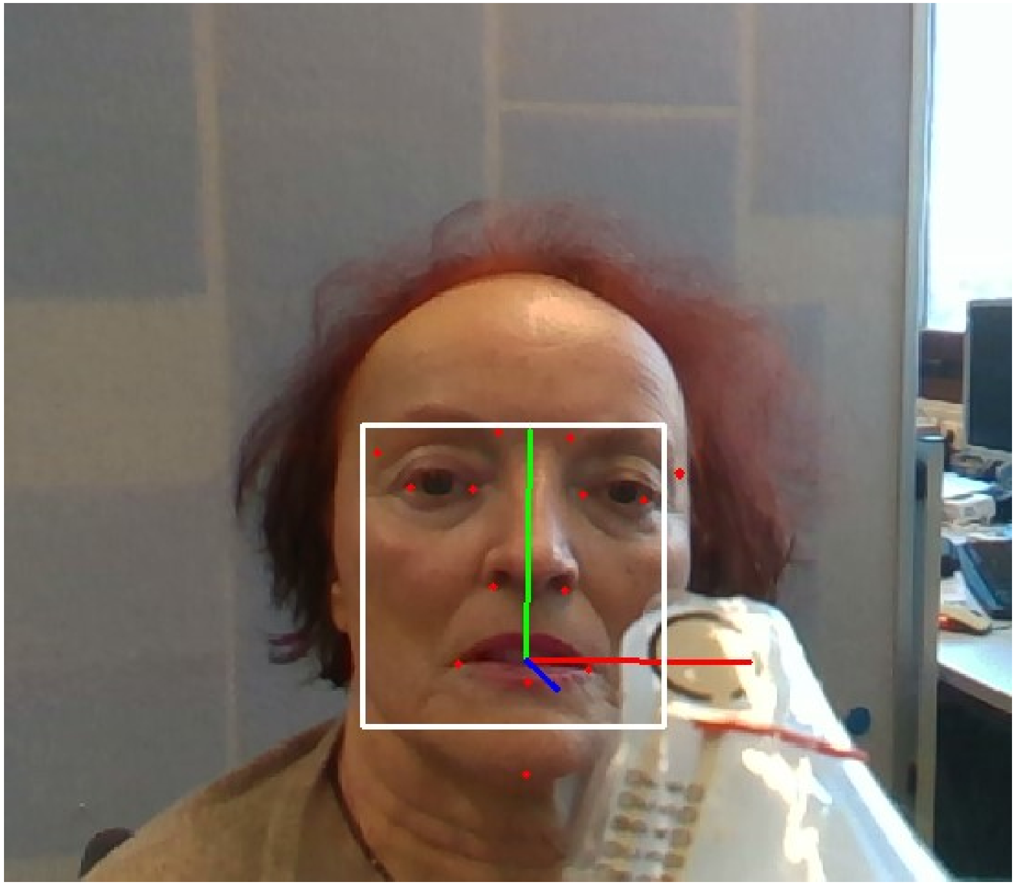

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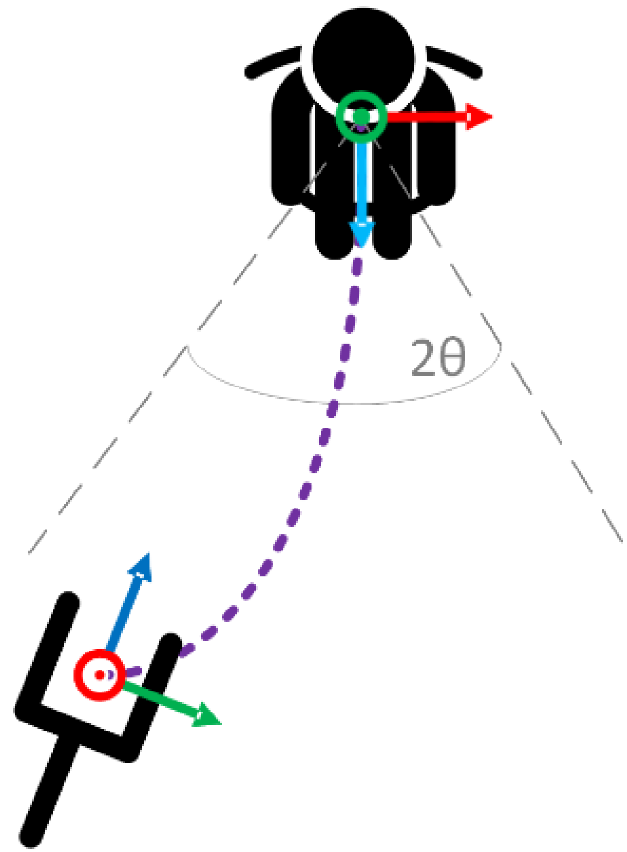

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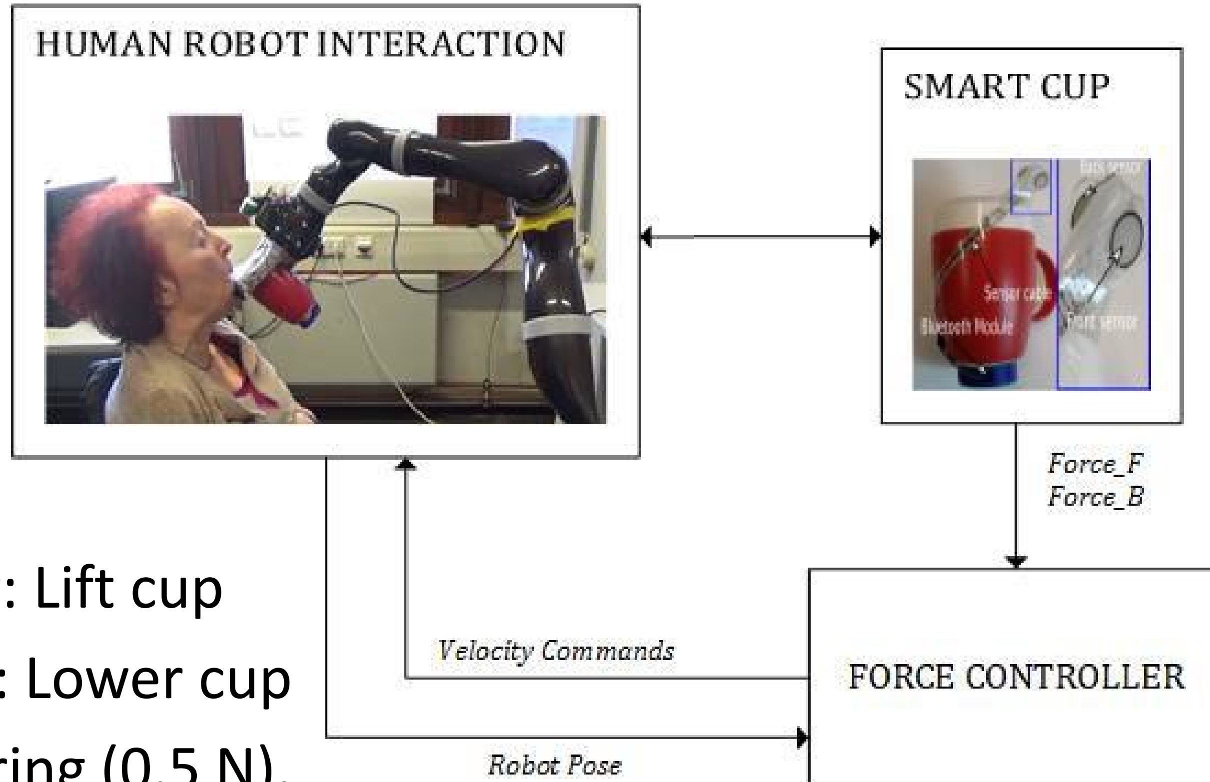
Force-based Control for the Drinking Process



- Force on front sensor: Lift cup
- Force on back sensor: Lower cup
- Thresholds for triggering (0.5 N), fall-back (1 N – both sensors) & safety (2.5 N)

Goldau F.F., Shastha, T.K., Kyrarini M., Gräser A., 2019. Autonomous Multi-Sensory Robotic Assistant for a Drinking Task. In *2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR).*

Video Contribution

Autonomous Multi-Sensory Robotic Assistant for a Drinking Task

Felix Ferdinand Goldau, Tejas Kumar Shastha, Maria Kyrarini, Axel Gräser

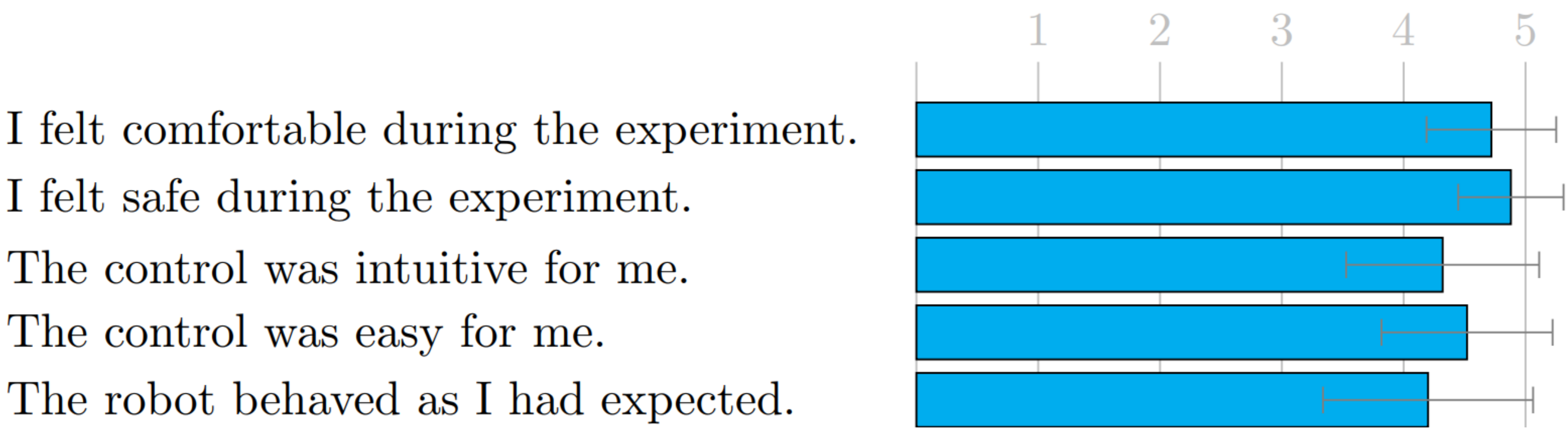
2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR)

Experimental Results

Serving the Cup:

25 participants (13 m, 12 f), including 1 with tetraplegia

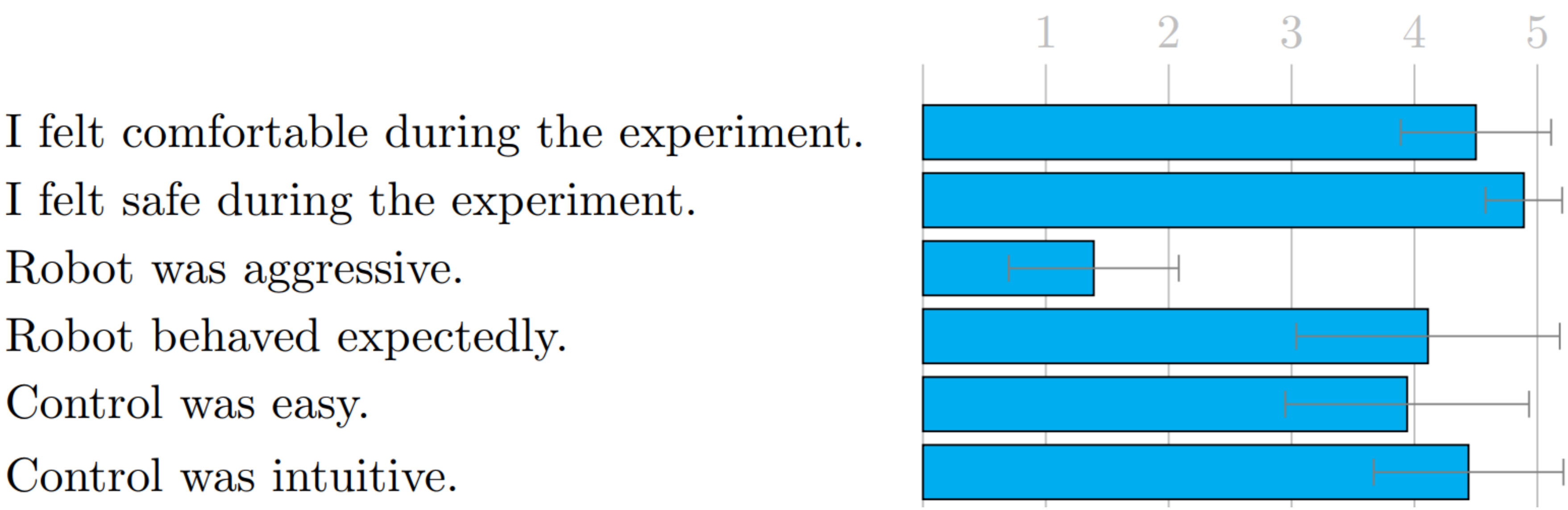
- Small abort rate (4%) and delay rate (7%)



Experimental Results

Drinking process:

16 participants (9 m, 7 f), including 1 with tetraplegia



Outlook

Users wished for:

- Higher Velocities for Safe Distances
- Normal cup
- User-controlled emergency stop
- Other types of tasks (e.g. cooking)

Assistive Robots in Collaborative Cooking

Assistive Robots in Collaborative Cooking

Human-Human Collaboration

Human-Robot Collaboration

Experimental Setup

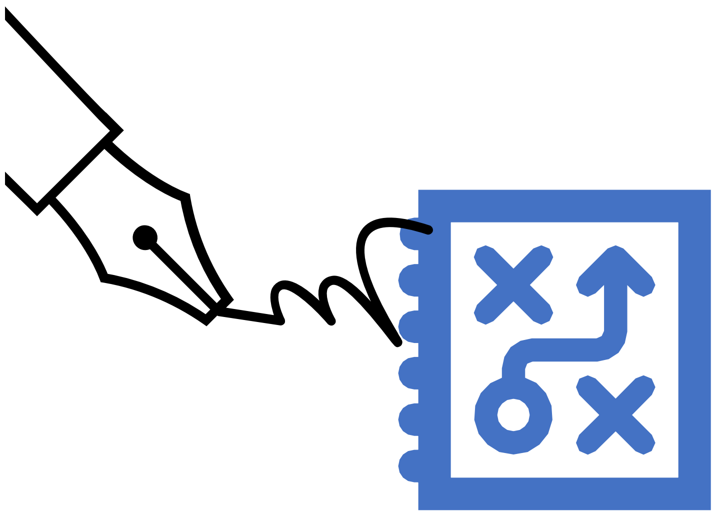
Created Dataset:
Collaborative Cooking Dataset (Transcripts)

Participants:
25 (14 male & 11 female) with a mean age of 35.4 years old and a standard deviation of 13.1.

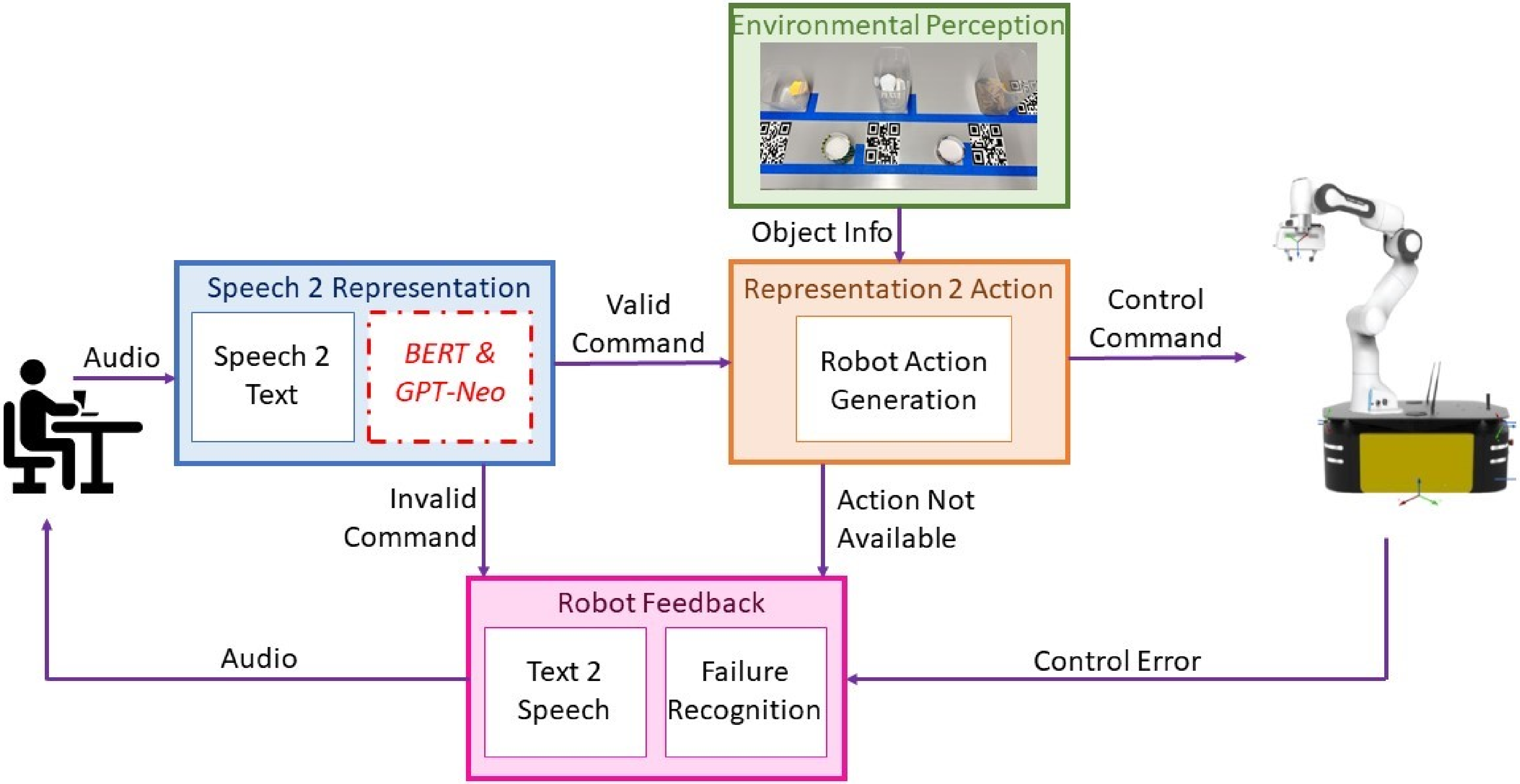
Procedure:
- Cook their favorite meal
- Say “Hey robot”
- Interruptions (e.g. talking, dog barking, etc.)

Experimental Study: Observations

- Interactive and engagement
- Started formal, then became more conversational
  Used more fragments phrases
- Some challenged the robot
- Some made-up names for ingredients and utensils
  “The other bowl”
- Some forgot the sequence
  “oh, I forgot …”



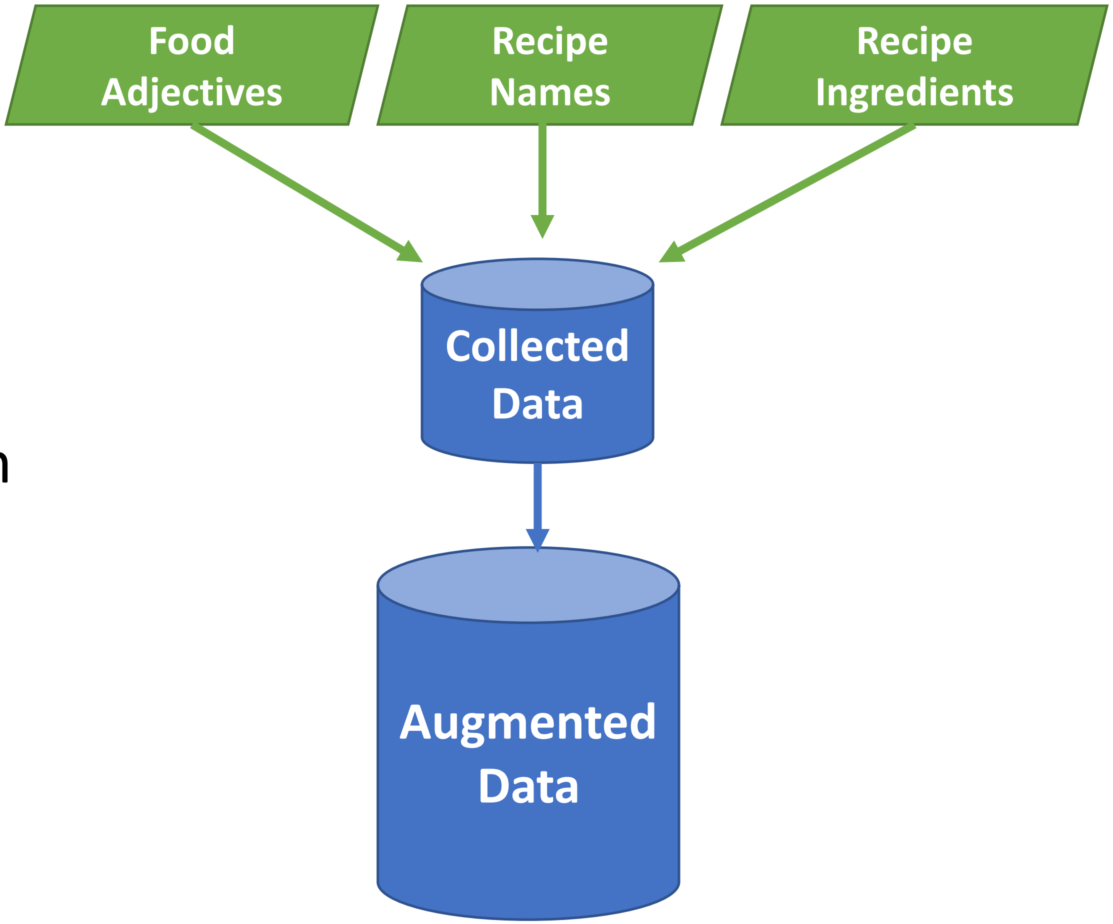
Speech2Action Framework



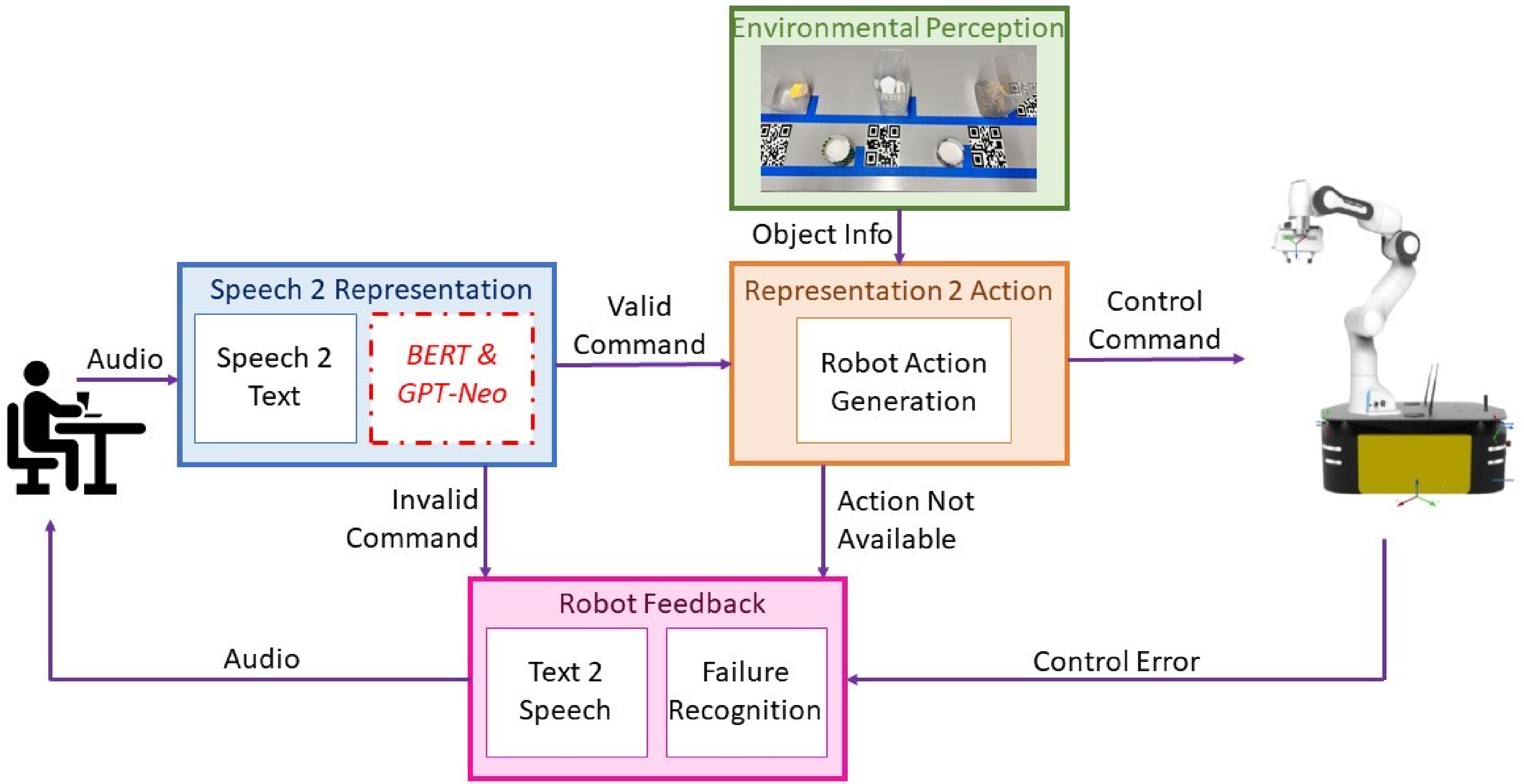
Kodur K., Zand M., Tognotti M.; Jauregui C., Kyrarini M. (2023). Structured and Unstructured Speech2Action Frameworks for Human-Robot Collaboration: A User Study. *TechRxiv. Preprint. https://doi.org/10.36227/techrxiv.24022452.v1*

Data Augmentation

- Language models require large amounts of data
- The data collected from 25 participants are not enough



Speech2Action Framework



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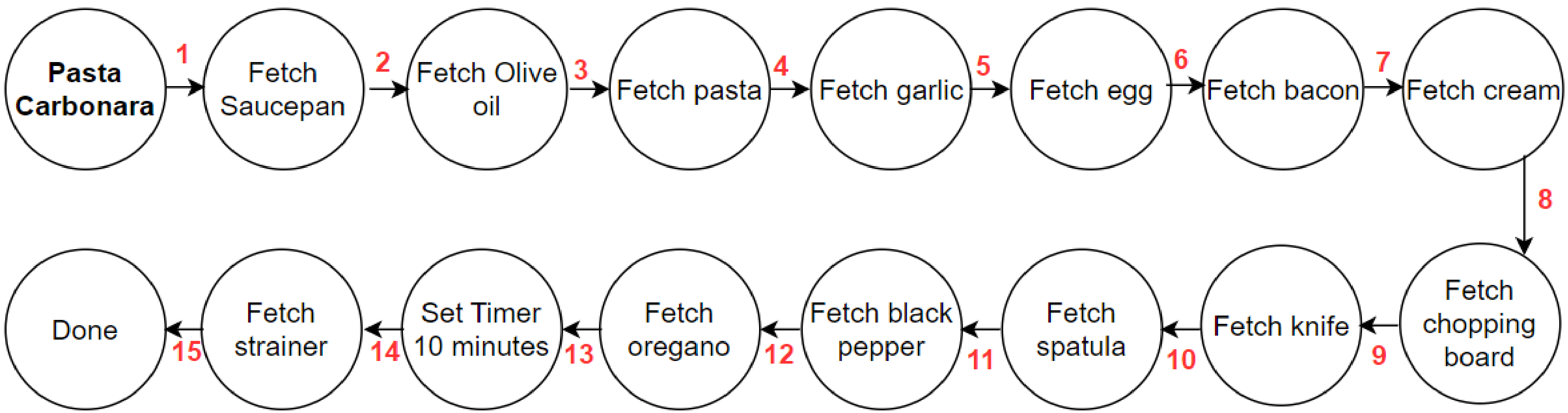
Example – Pasta Carbonara



User Study

Participants:

30 participants: 8 (26.6% of participants) were female, and 22 were male - faculty, students, visitors, and staff from the School of Engineering at Santa Clara University

Two modes of communication:

- Structured and unstructured
- Counterbalanced approach

Errors:

- Speech to Text Errors
- BERT & GPT-NEO Errors
- Robot Errors

Statistical Analysis

Hypothesis 1: Individuals exposed to unstructured robot interaction via spoken language will demonstrate a higher preference for this mode of interaction compared to structured robot interaction.

Hypothesis 2: The individual's perception of robots will be negatively affected when they encounter robot failures during the interaction, as opposed to instances without or with minimal failures.

Hypothesis 3: The individual's preferred method of instructing the robot, whether structured or unstructured, will be influenced by their previous experiences with robot failures during the interaction, based on the respective method.

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User Study

Participants (+5 females):

35 participants: 13 were female, and 22 were male - faculty, students, visitors, and staff from the School of Engineering at Santa Clara University

Two modes of communication:

- Structured and unstructured
- Counterbalanced approach

Errors:

- Speech to Text Errors
- BERT & GPT-NEO Errors
- Robot Errors

Statistical Analysis

Hypothesis 4. The average number of words in each command used for instructing the robot is affected by how the person perceives the robot's interaction and the robot errors occurring during the interaction. ✓

Hypothesis 5. The politeness level of the person commanding a robot positively correlates with their positive perception of the robot interaction. ✓

Hypothesis 6. There is a correlation between the sentiment expressed during human-robot interaction and how individuals perceive the quality and effectiveness of that interaction. ✓

Hypothesis 7. Gender plays a significant role in how individuals perceive trust and safety when interacting with robots, with variations in trust and safety perceptions between genders. ?

Dataset

Datasets

Structured and Unstructured Speech2Action Frameworks for Human-Robot Collaboration: A User Study

Preprint | Dataset Link | Demo

hmi2.org -> Datasets

Outlook

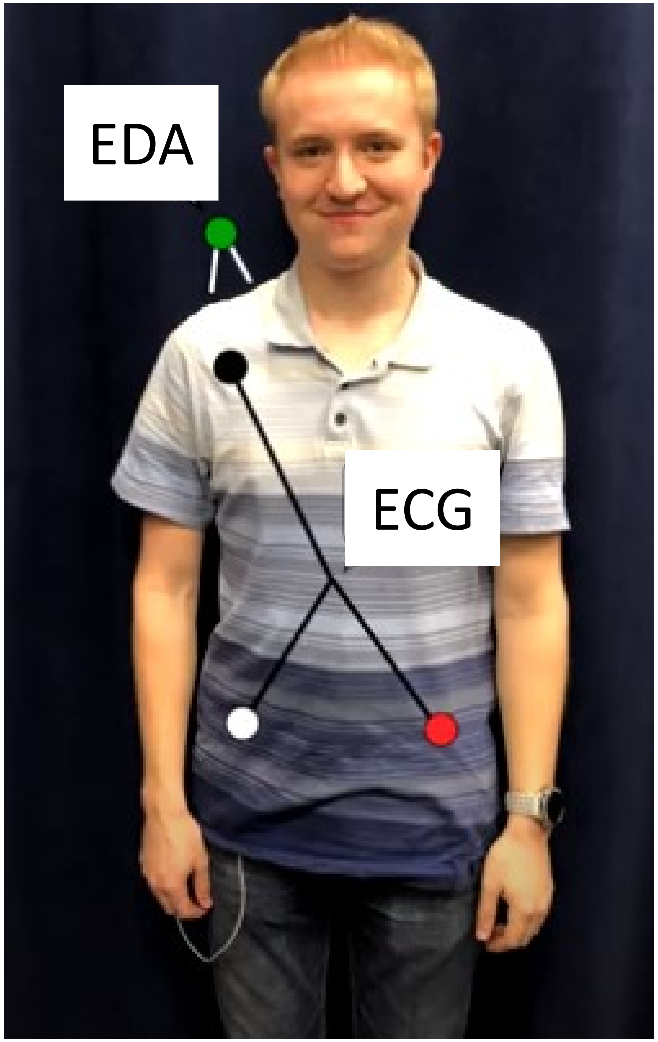
- ✓ Natural way of communication between the robot and the human
- ✓ Robot automatically generates actions for a task using spoken language

- ❑ Adding additional actions (e.g. timer)
- ❑ Learning from day to day interactions
- ❑ Making the robots more understanding when we are tired

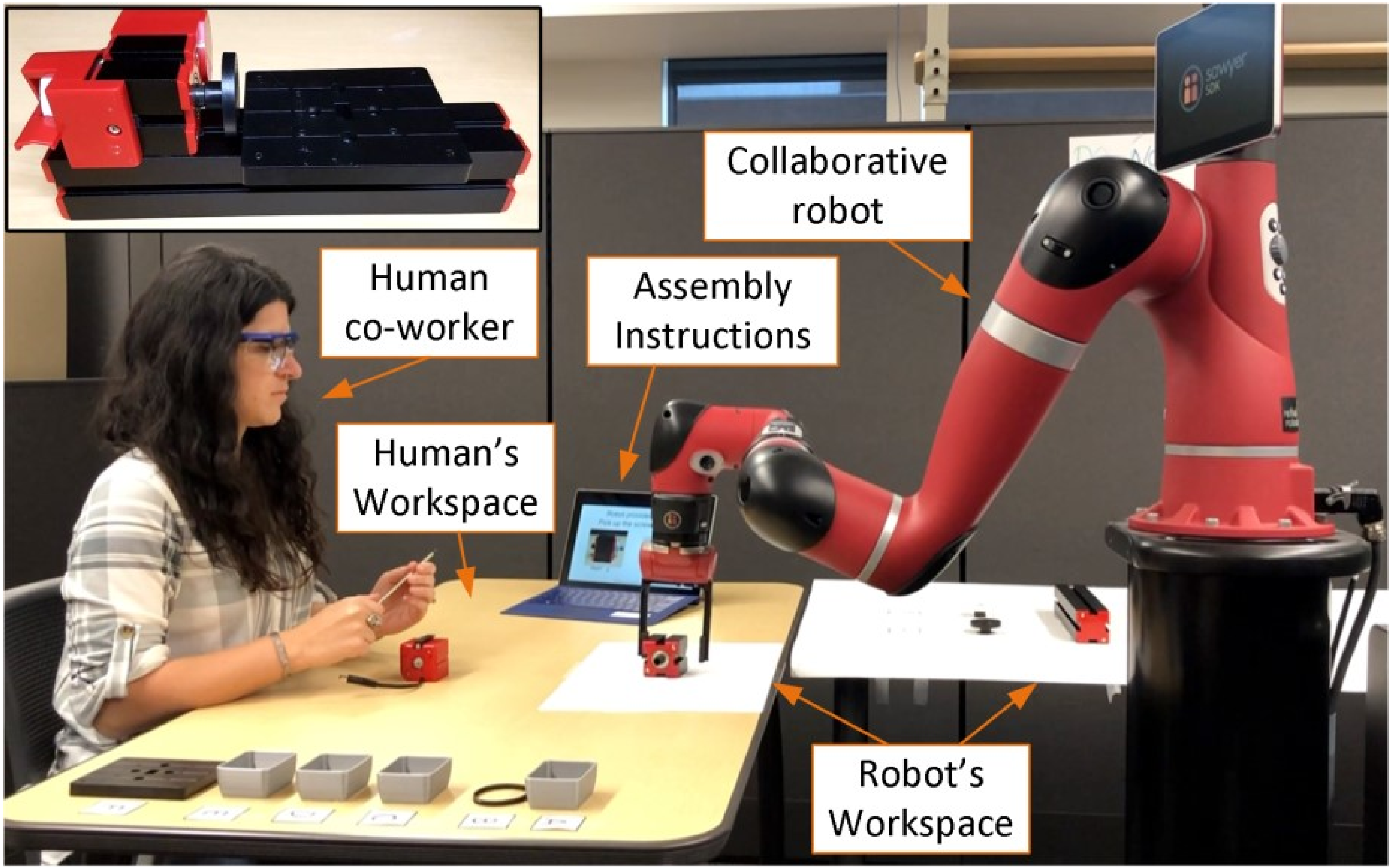
Making Robots More Understanding

Can robots understand how their human teammates feel?

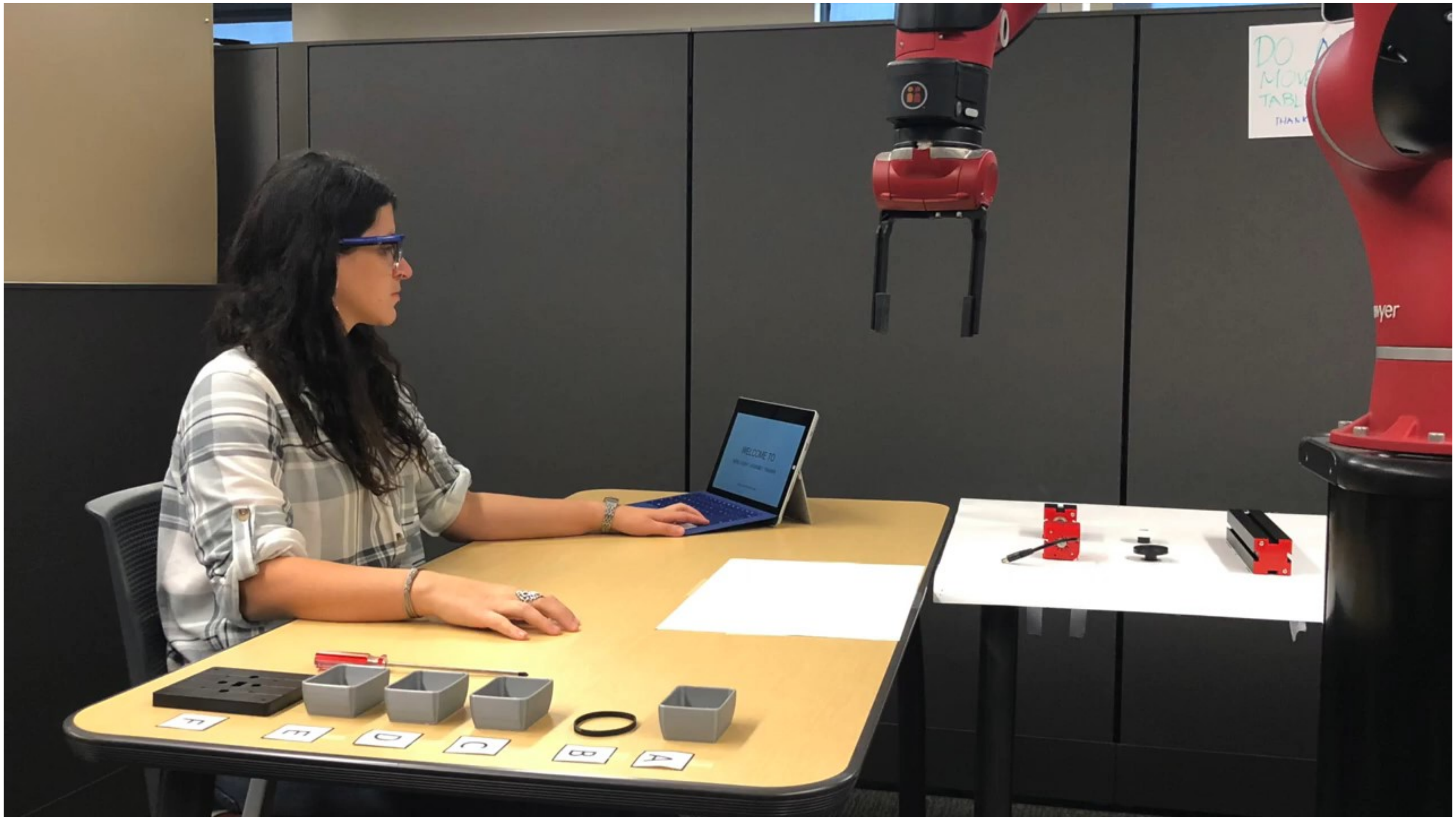
- **Cognitive Load Assessment** during Human-Robot Collaboration
- **Multi-sensory System**: Electrocardiography (ECG) & Electrodermal Activity (EDA).



RoboAssist System



RoboAssist System



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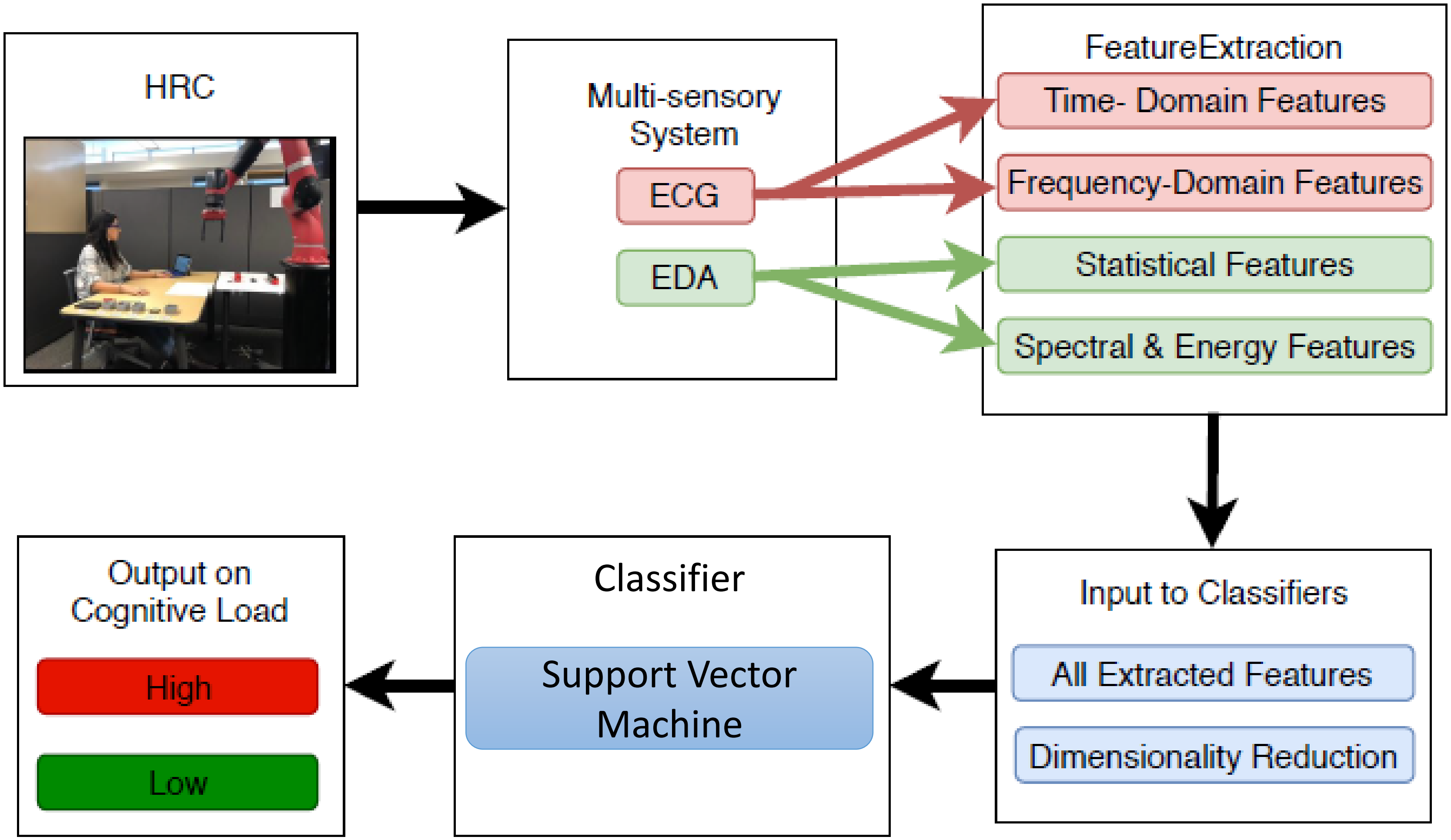

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Experimental Results

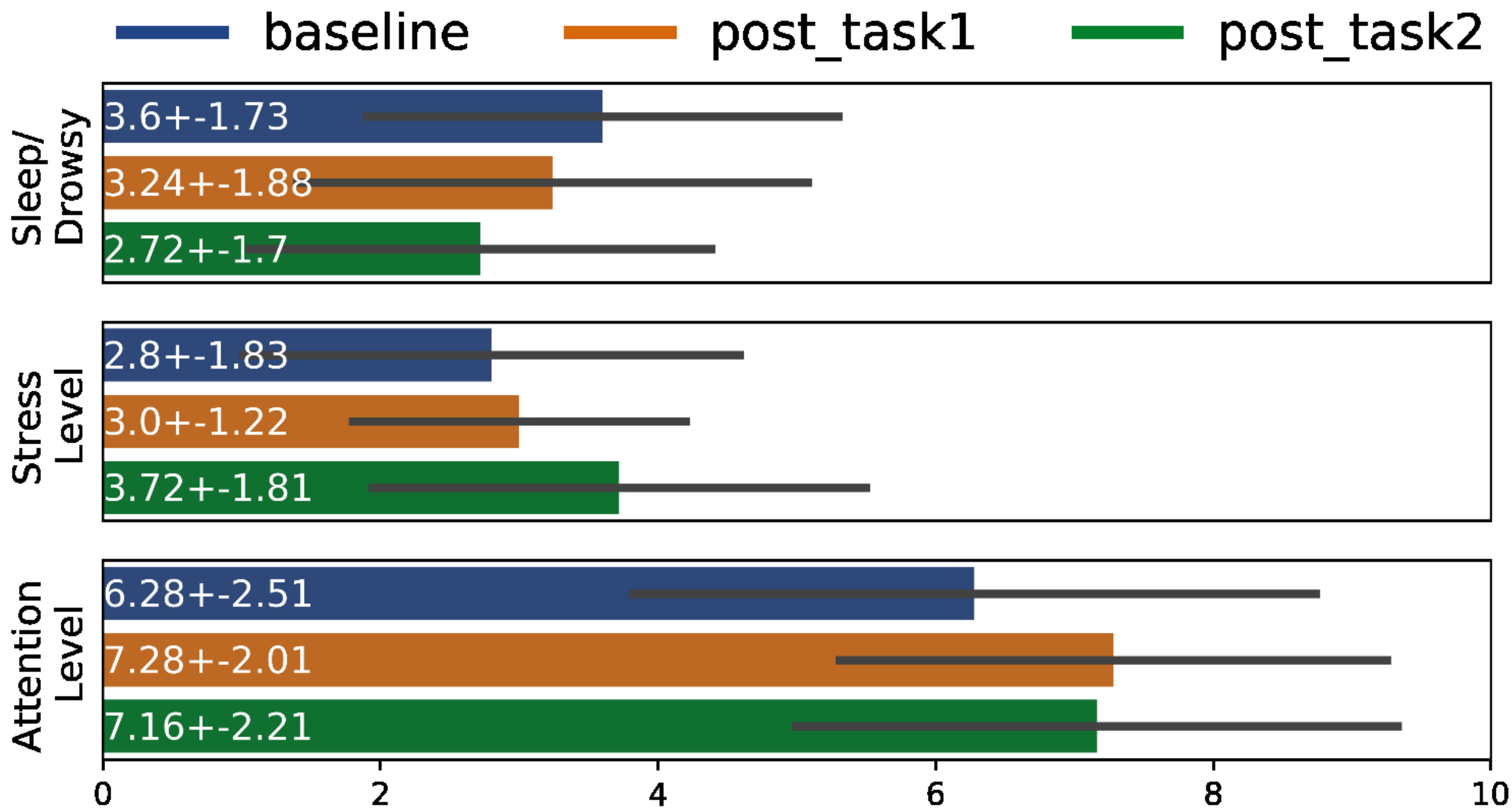
Pilot study

- 25 participants (10 female, 15 male)
- 6 of the participants had prior experience in Robotics

Experimental procedure

- **1st session – Low Cognitive Load:** the collaborative assembly task
- **2nd session – High Cognitive Load:** same assembly task with **time constraints** to induce stress and high cognitive load (30 seconds for each step)

Subjective feedback



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Experimental Results

- Training set: 16 participants, Testing set: 6 participants
- Machine learning evaluation results for all extracted features

	SVM
	Acc
ECG	42.85
EDA	71.42
ECG+EDA	92.85

- Machine learning evaluation results with Principal Component Analysis (PCA)
  (C is the number of PCA components)

	SVM	
	C	Acc
ECG	4	57.14
EDA	10	78.57
ECG+EDA	15	92.85

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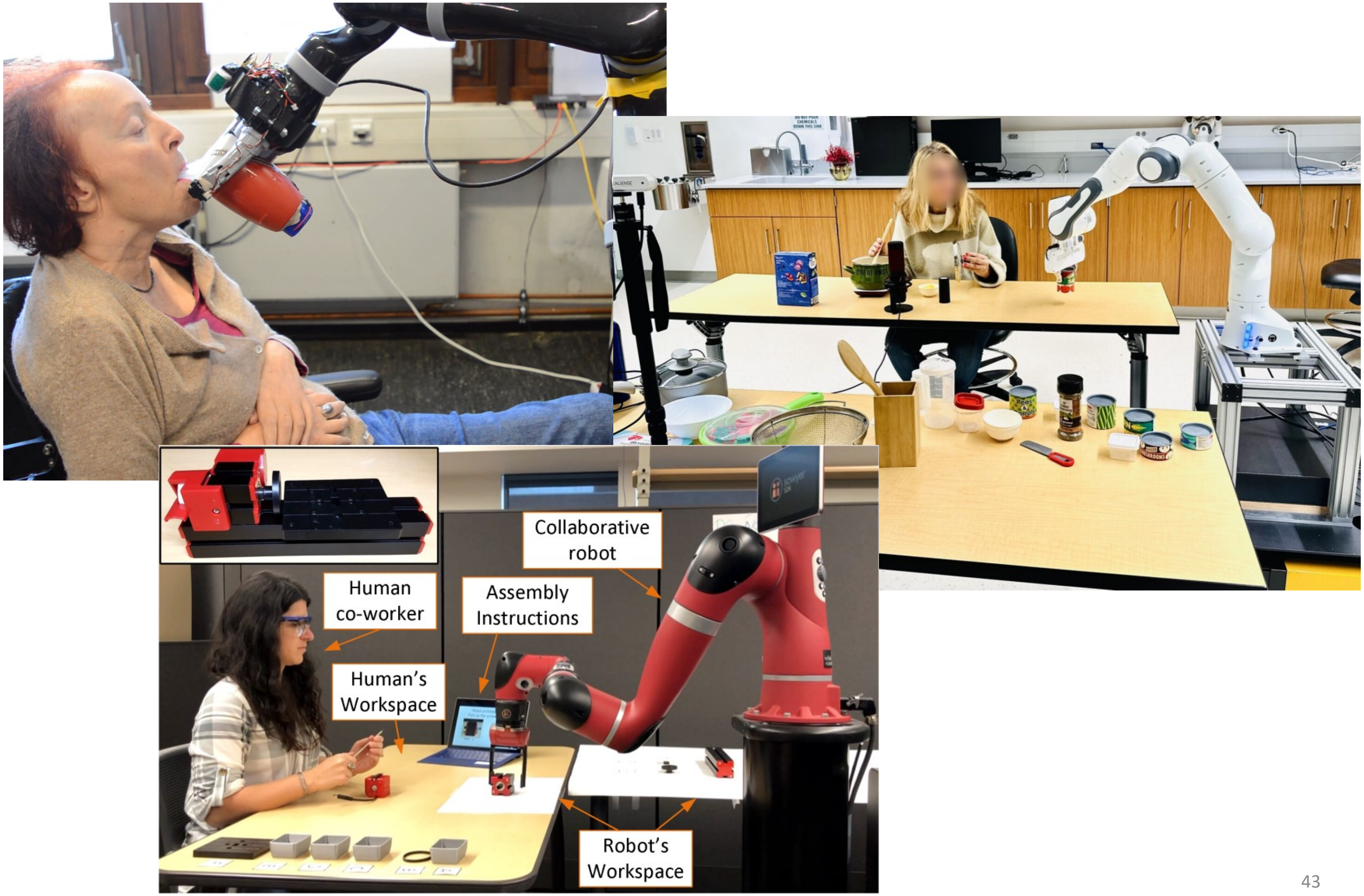
Outlook

- ✓ Cognitive Load Assessment during Human-Robot Interaction
- ✓ Smart T-shirt

- ❑ Expand on Cognitive Fatigue Assessment
- ❑ Focus on: People with Paralysis

Conclusion



Collaborative robot
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Acknowledgments

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Federal Ministry of Education and Research

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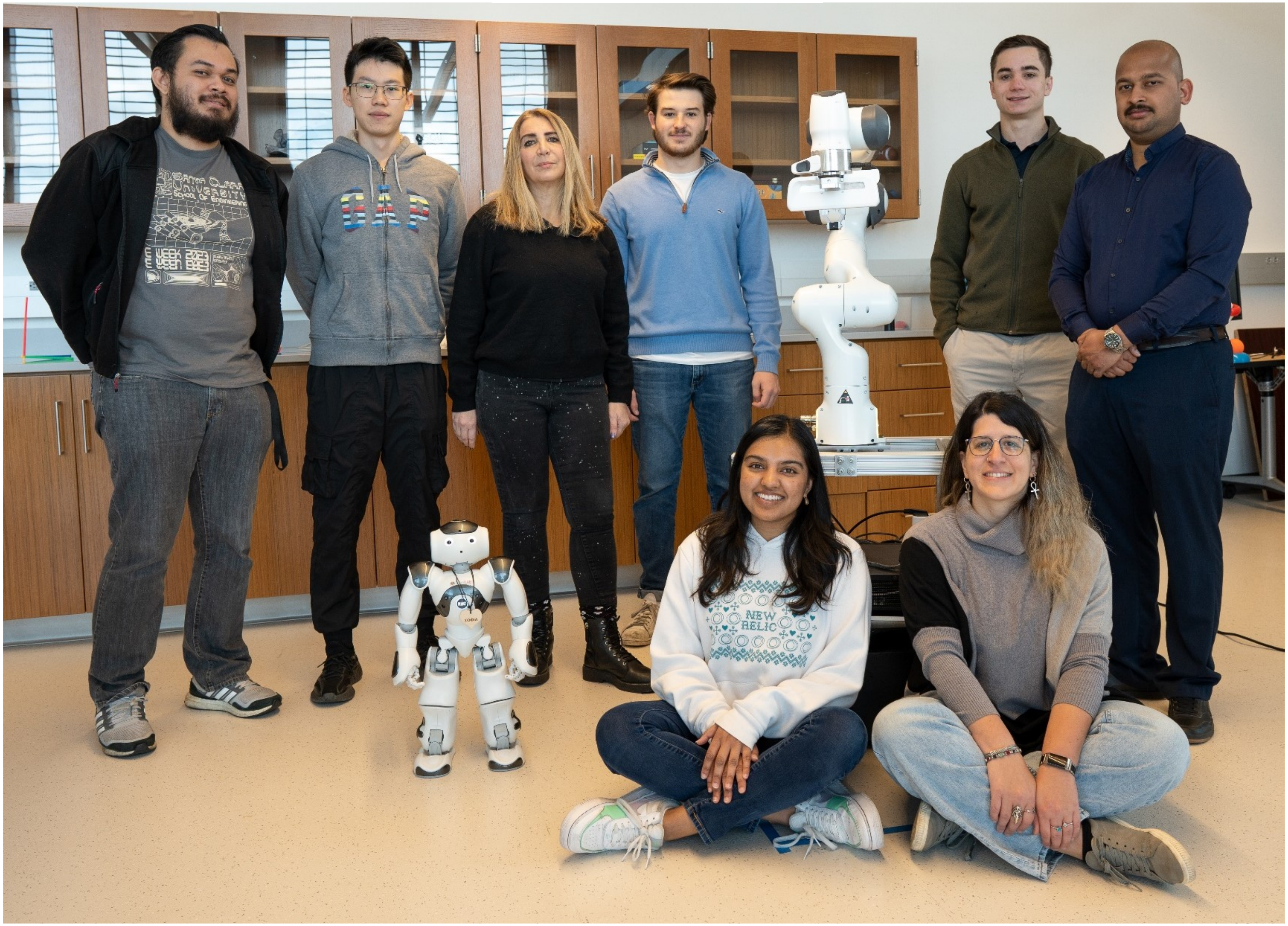

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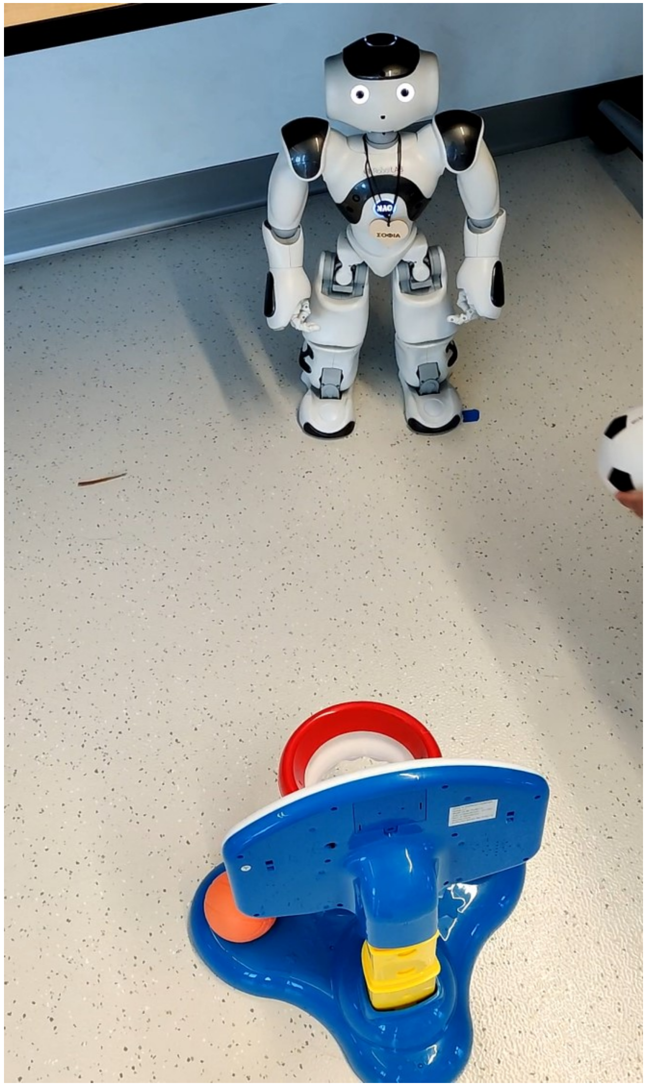

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