

# Human-Robot Interaction

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COMPUTER SCIENCE & ENGINEERING  
UNIVERSITY *of* WASHINGTON

**April 21, 2014**

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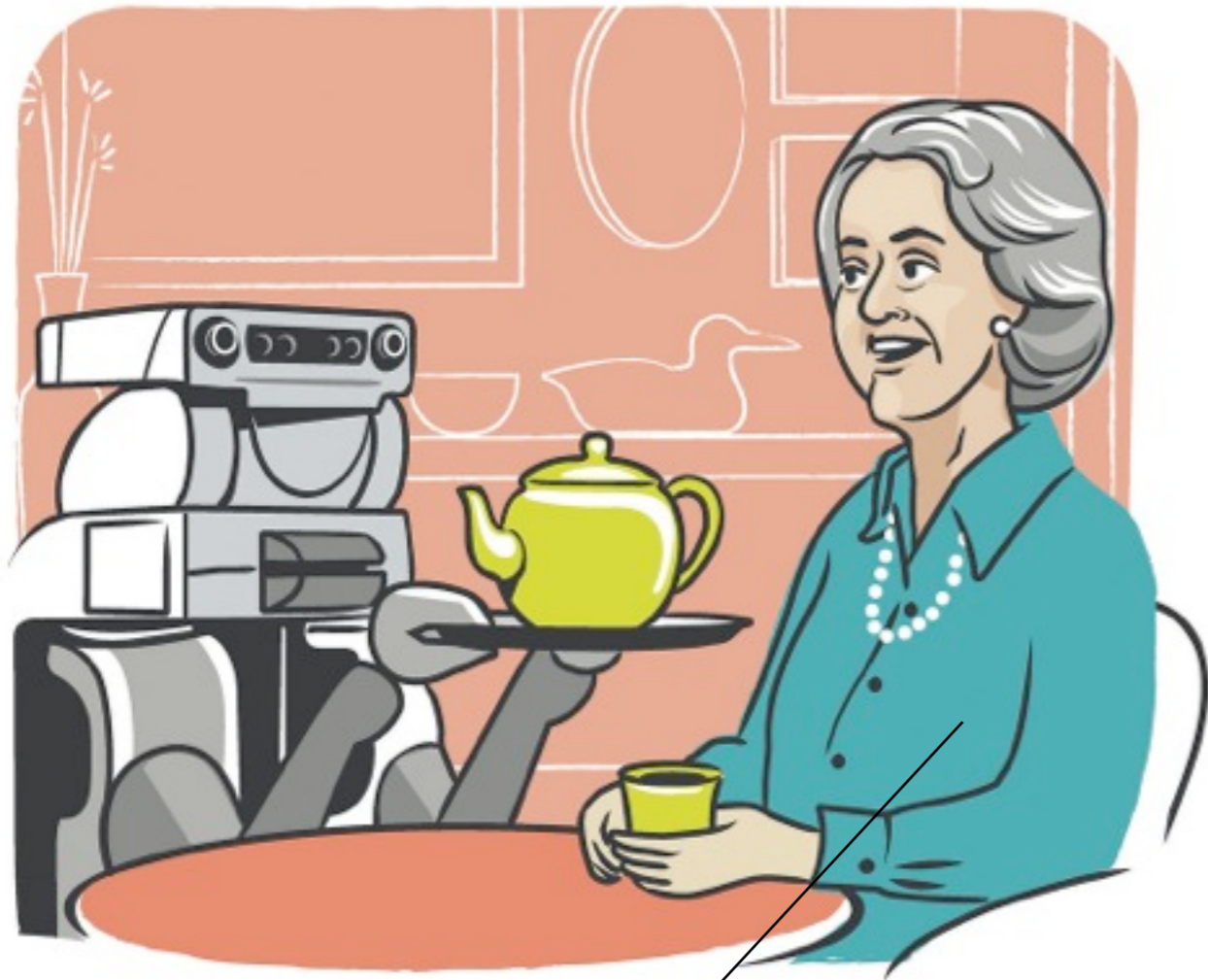
**April 21, 2014**

# PLAN

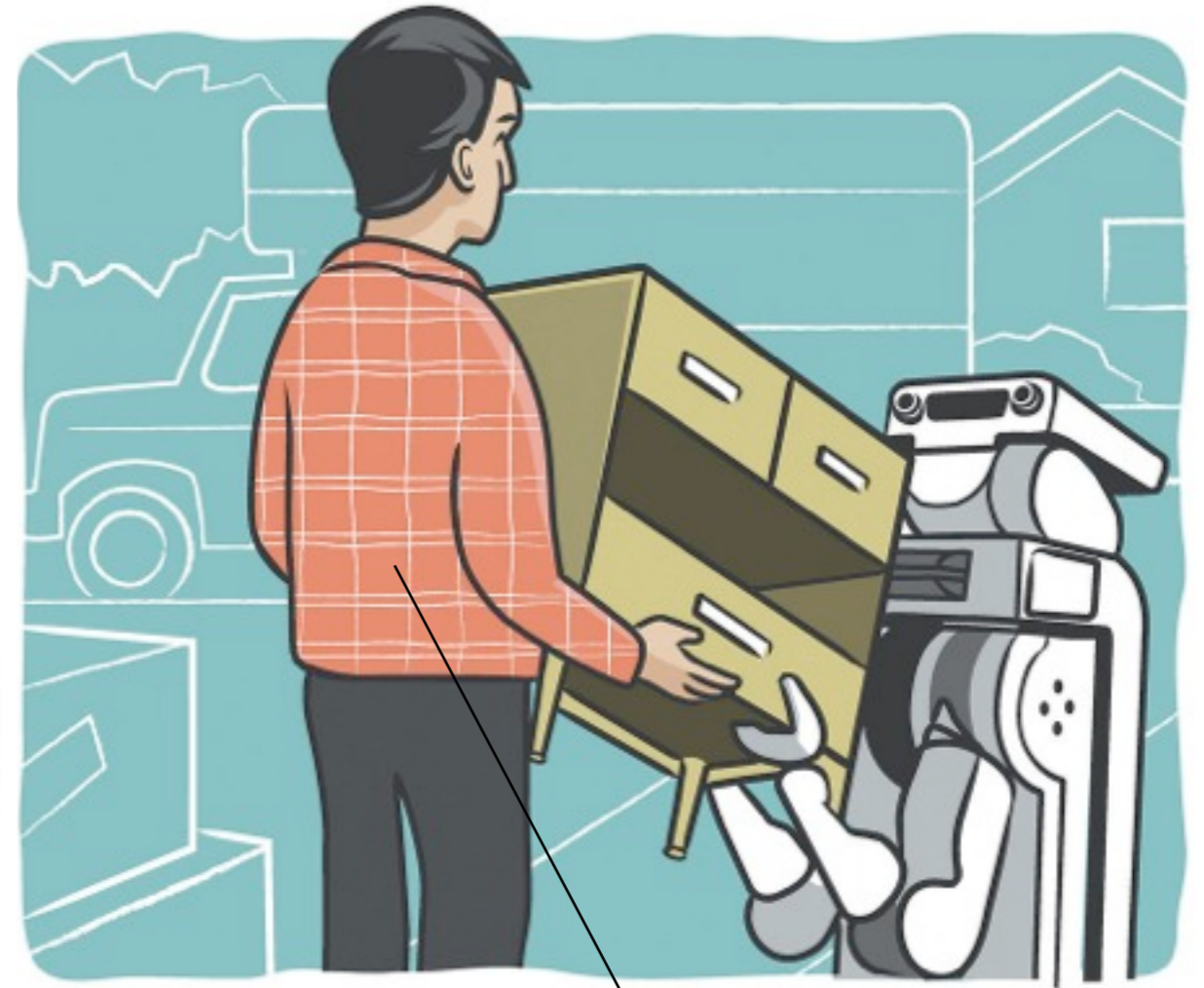
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- What is HRI?
- Maya's research in HRI
- Discussion: How is HRI different from HCI?
- Methods in HRI

# HUMAN-ROBOT INTERACTION



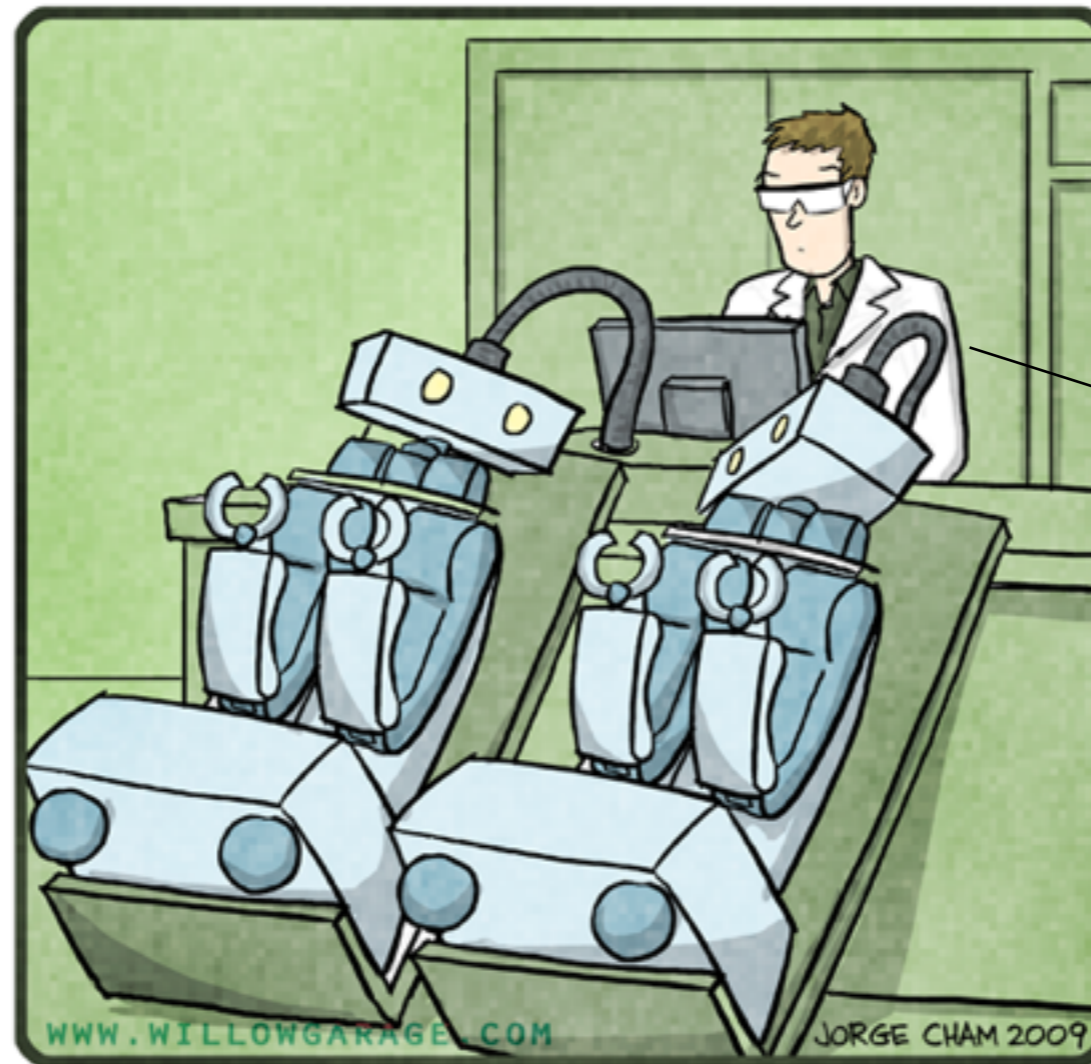
*commanding a robot*



*collaborating with a robot*



# HUMAN-ROBOT INTERACTION



*programming a robot*

# ABOUT ME



Georgia Institute of Technology, 2012



Willow Garage, Inc, 2013

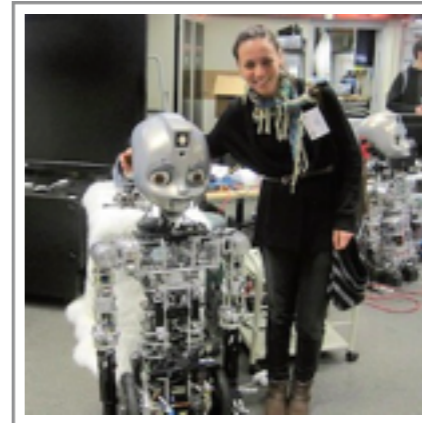
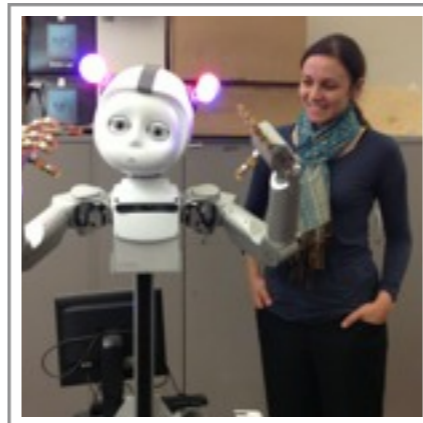
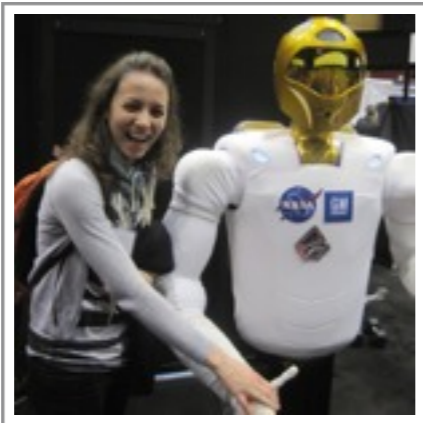
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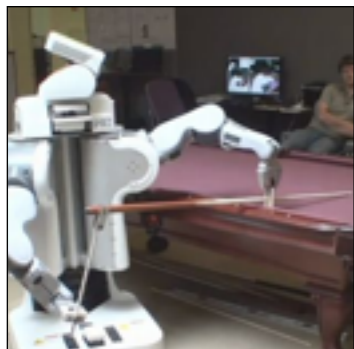


I <3 robots



# GENERAL-PURPOSE ROBOTS

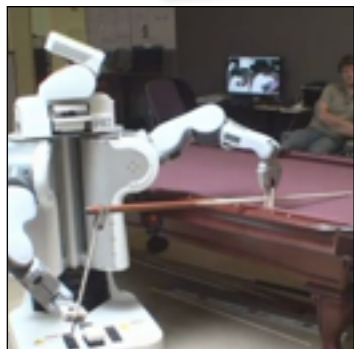
One robot, many uses...





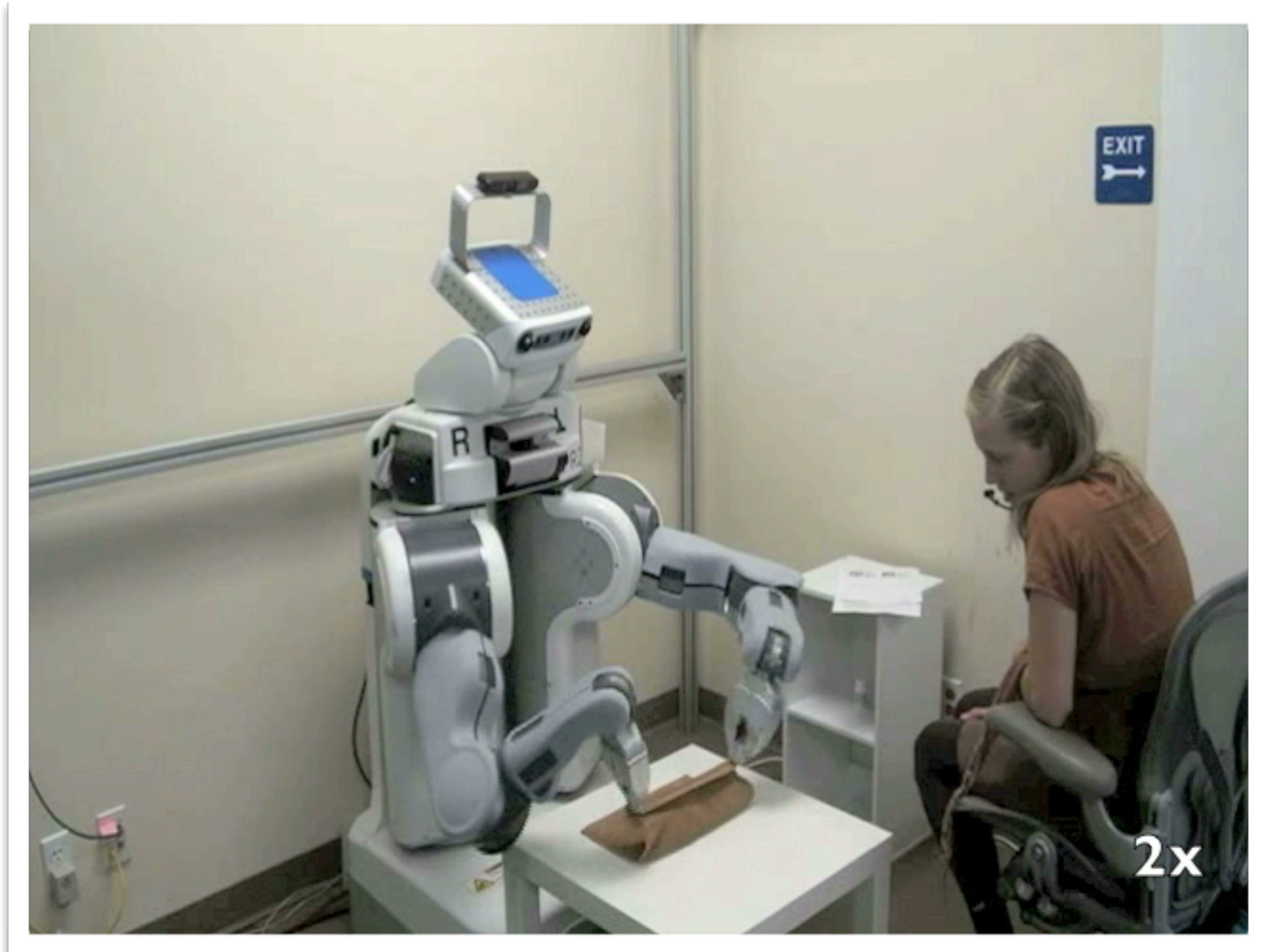
# GENERAL-PURPOSE ROBOTS

... but programming it is hard!





# END-USER PROGRAMMABLE ROBOTS



# WHY IS IT CHALLENGING?

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Existing tools assume good teachers...

- ▶ large number of demos
- ▶ variance in demos
- ▶ smooth/consistent demos



# WHY IS IT CHALLENGING?

---

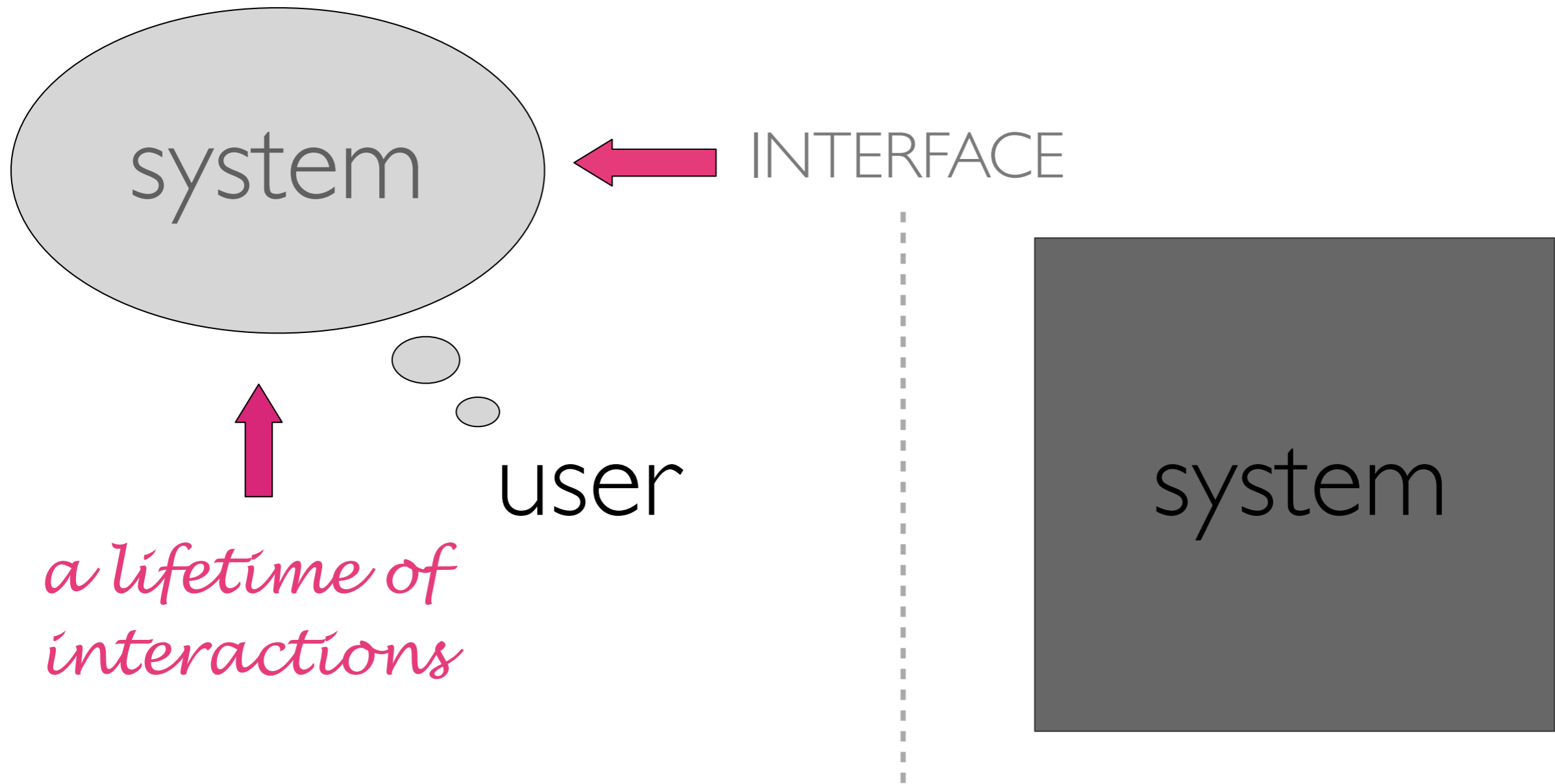
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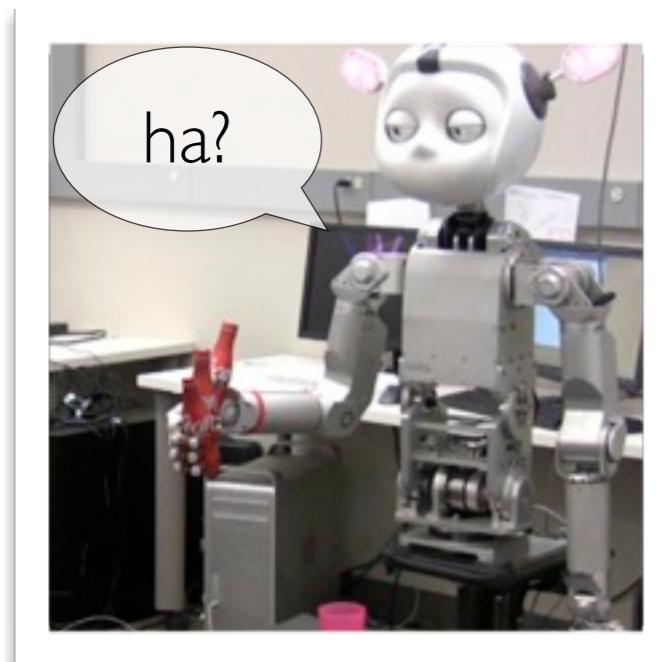
... everyday users are not!

- ▶ limited time, patience, attention, memory
- ▶ inaccurate mental model

# MENTAL MODEL ALIGNMENT



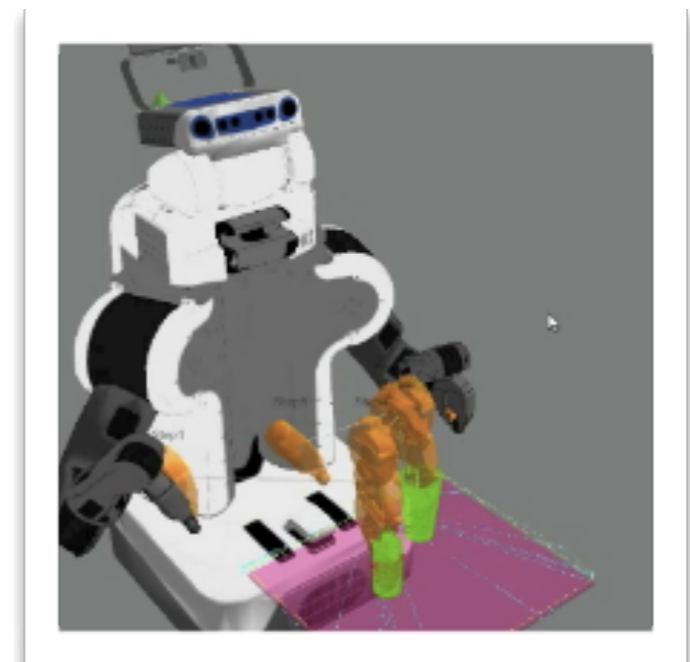
# MENTAL MODEL ALIGNMENT



Make robot  
ask questions

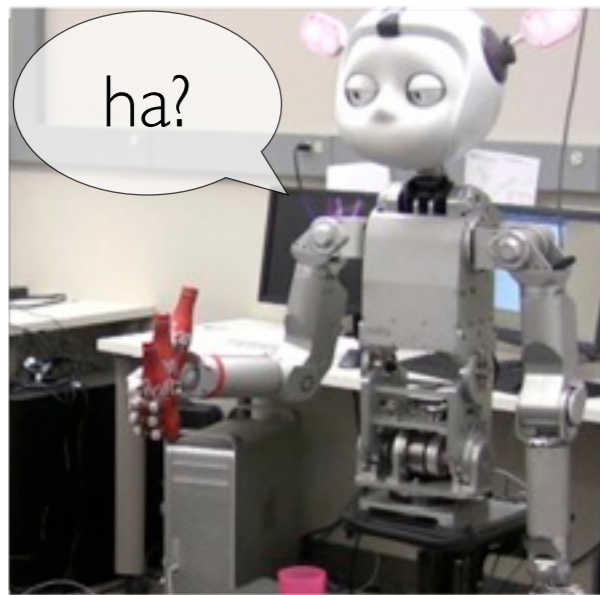


Instruct or  
train users



Simplify and  
visualize model

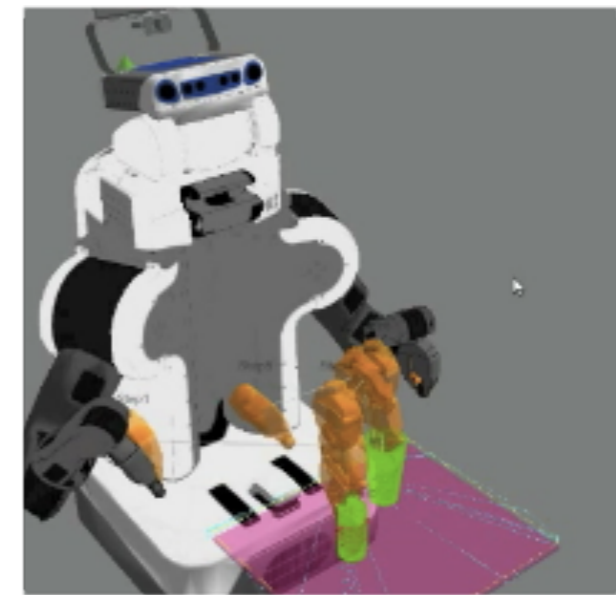
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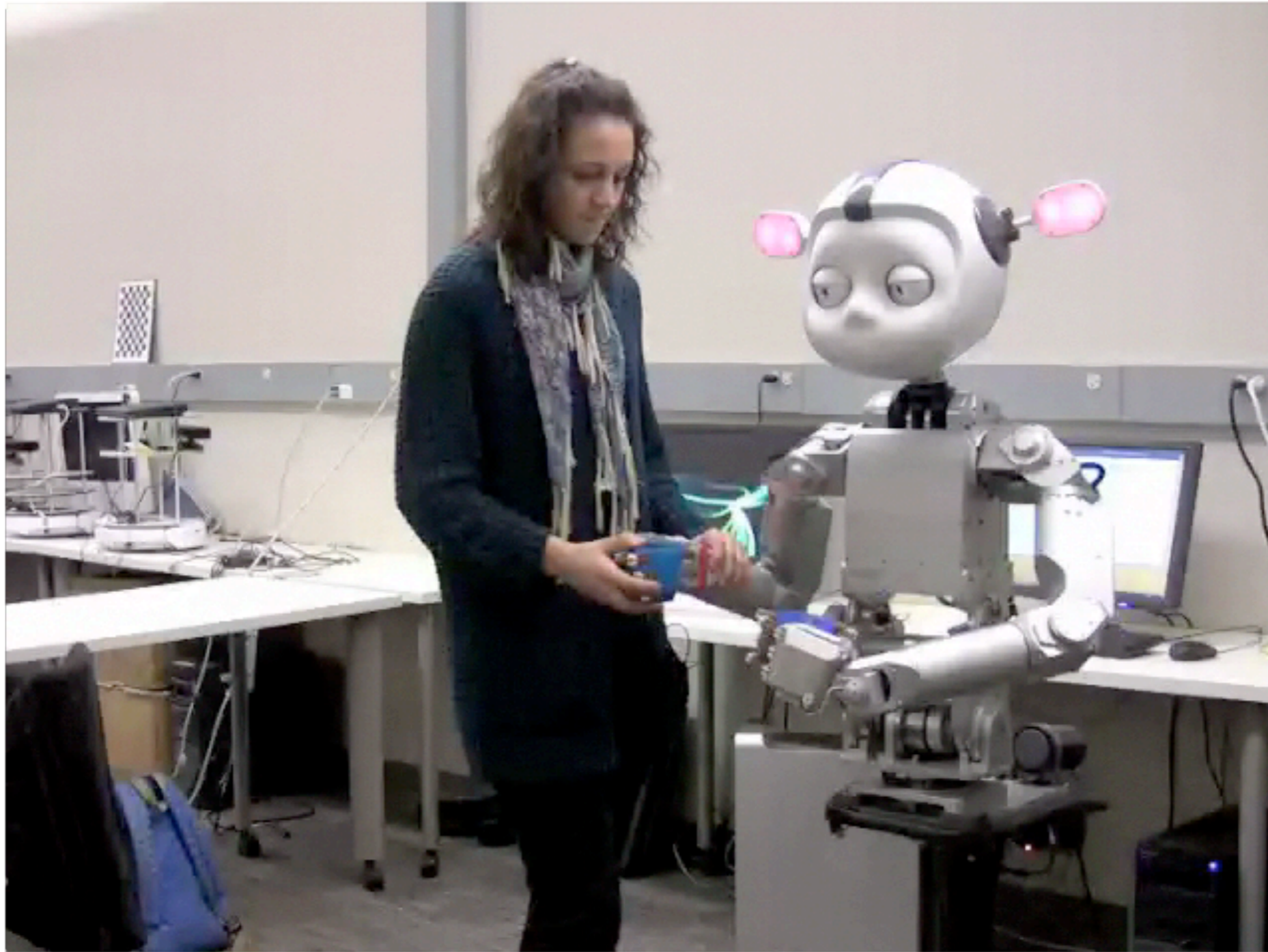


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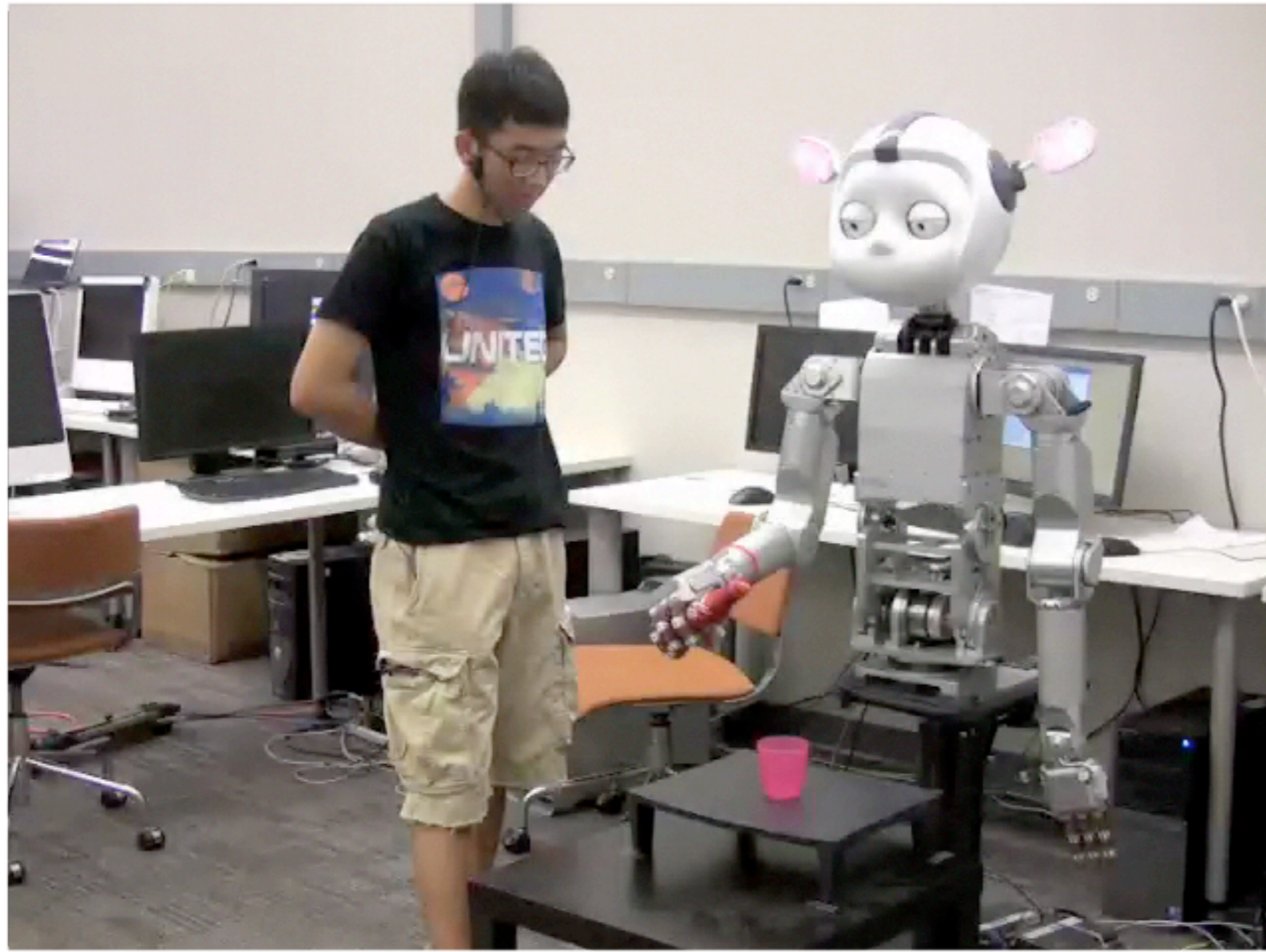
Simplify and  
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# ROBOTS THAT ASK QUESTIONS

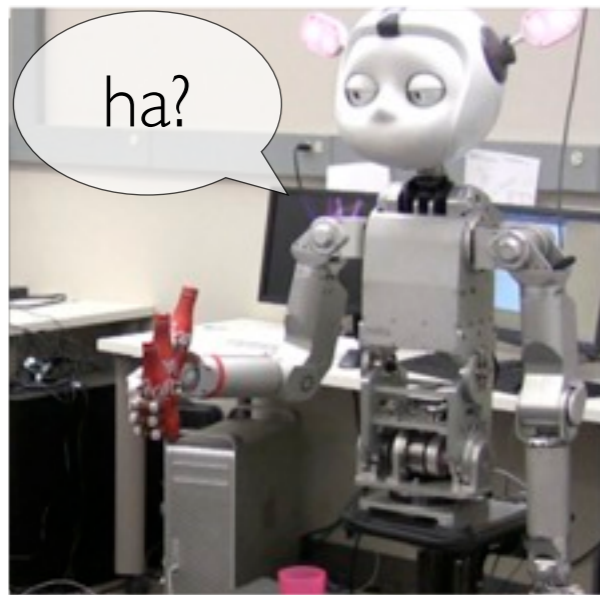




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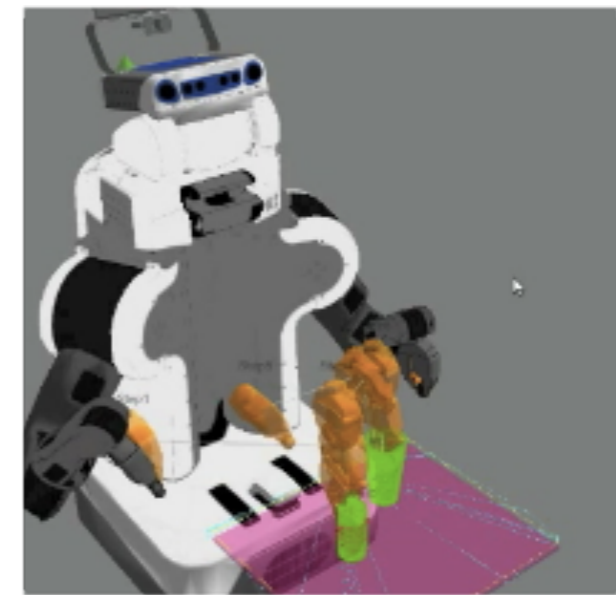
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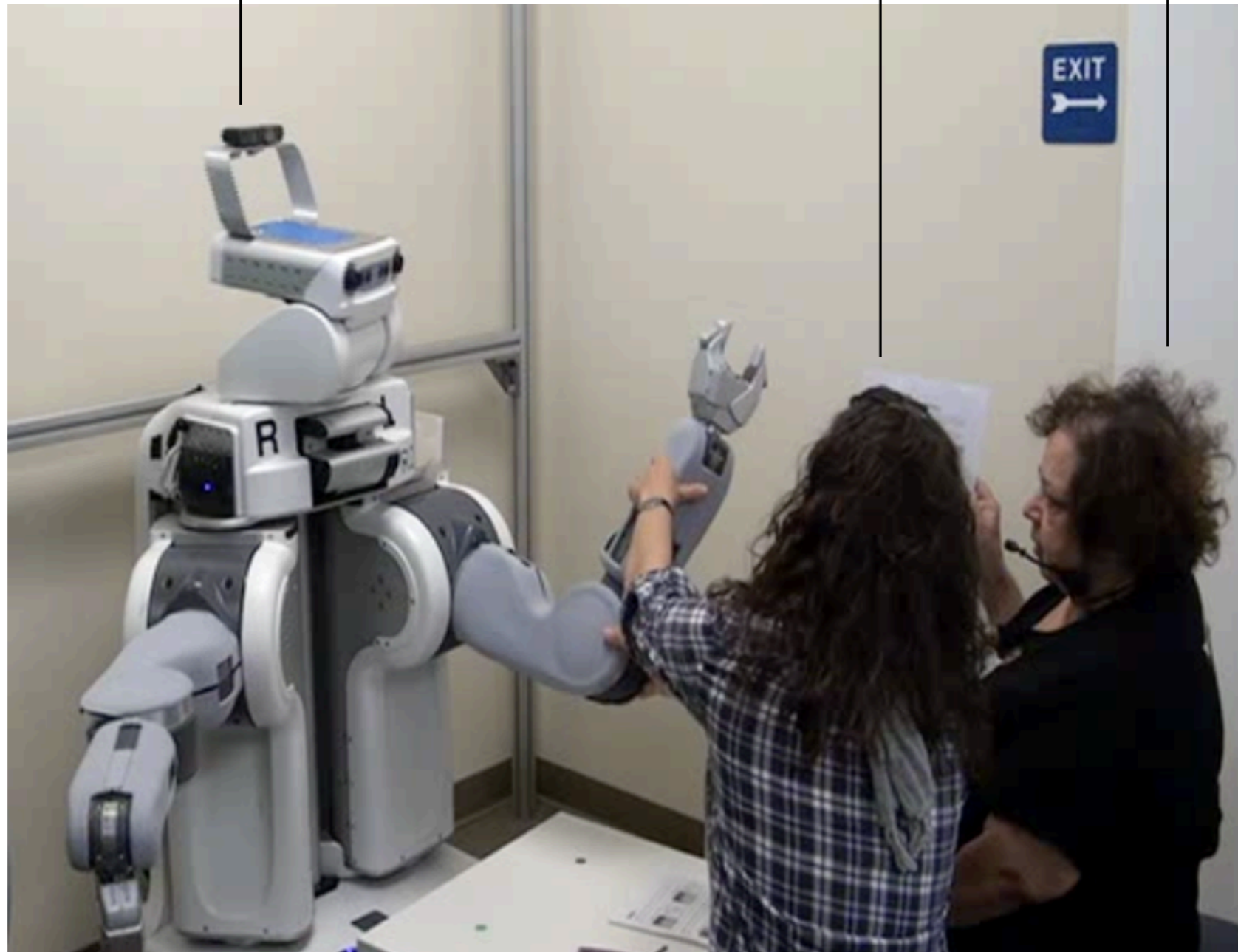


# HOW TO INSTRUCT USERS

ROBOT

EXPERIMENTER

USER

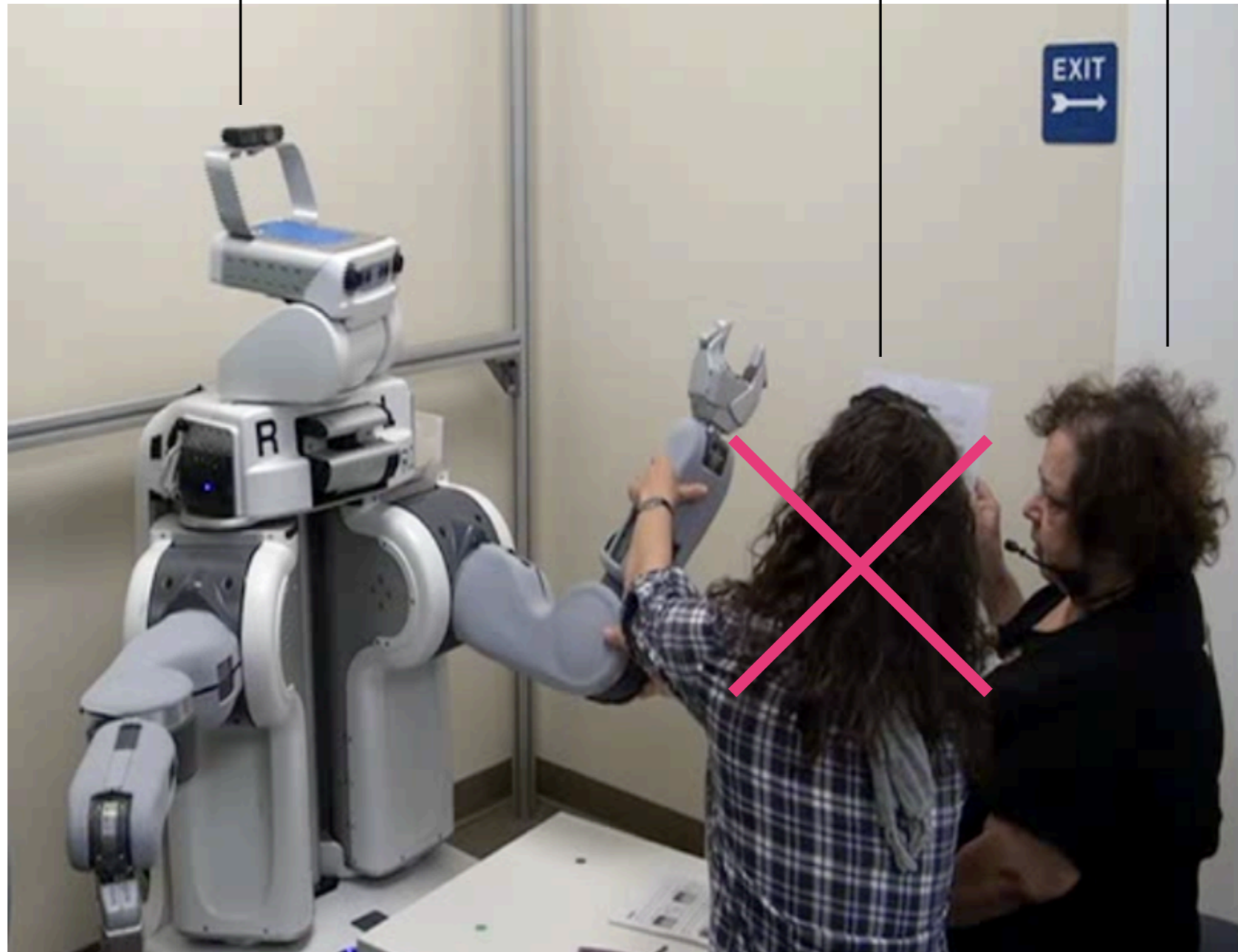


# HOW TO INSTRUCT USERS

ROBOT

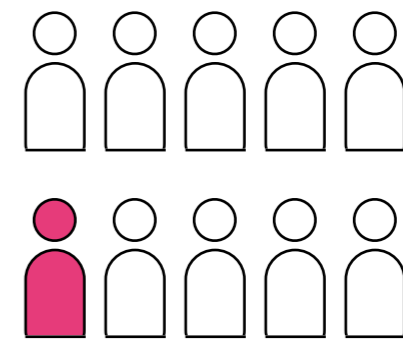
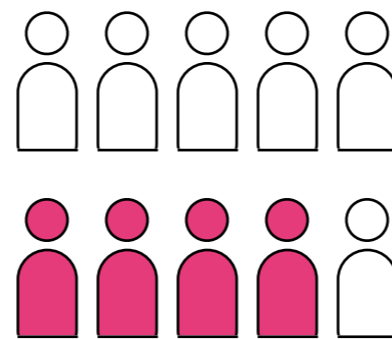
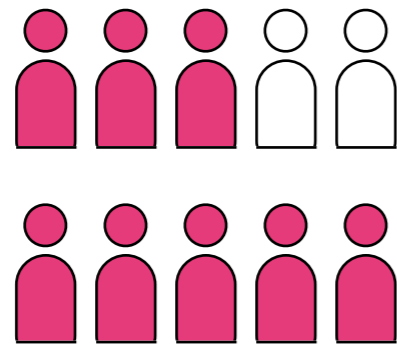
EXPERIMENTER

USER



# INSTRUCTIONAL MATERIALS

number of participants who requested tech support



BASELINE



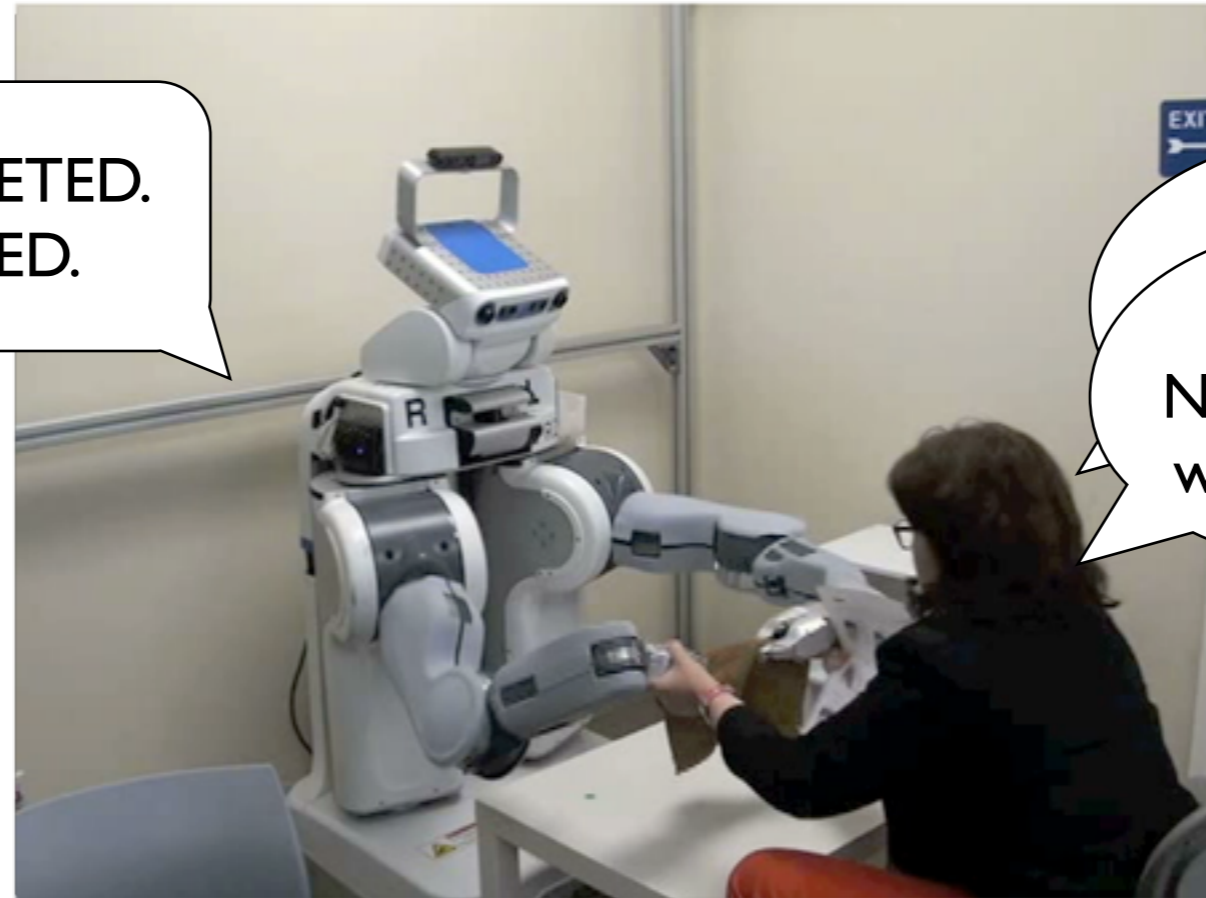
TUTORIAL



VIDEO

# INSTRUCTIONAL MATERIALS

ALL POSES DELETED.  
SKILL CLEARED.



What?!?  
No, that's not  
what I said!

number of uses of UNDO LAST COMMAND

TUTORIAL



VIDEO



1

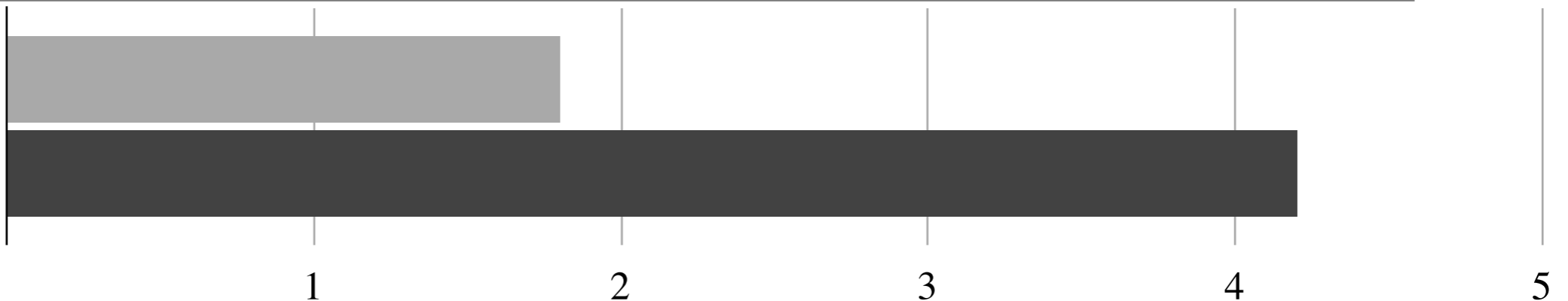
2

3

4

5

*Number of uses*



# INTERACTION DESIGN

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appropriate **feedback** reduces learning load



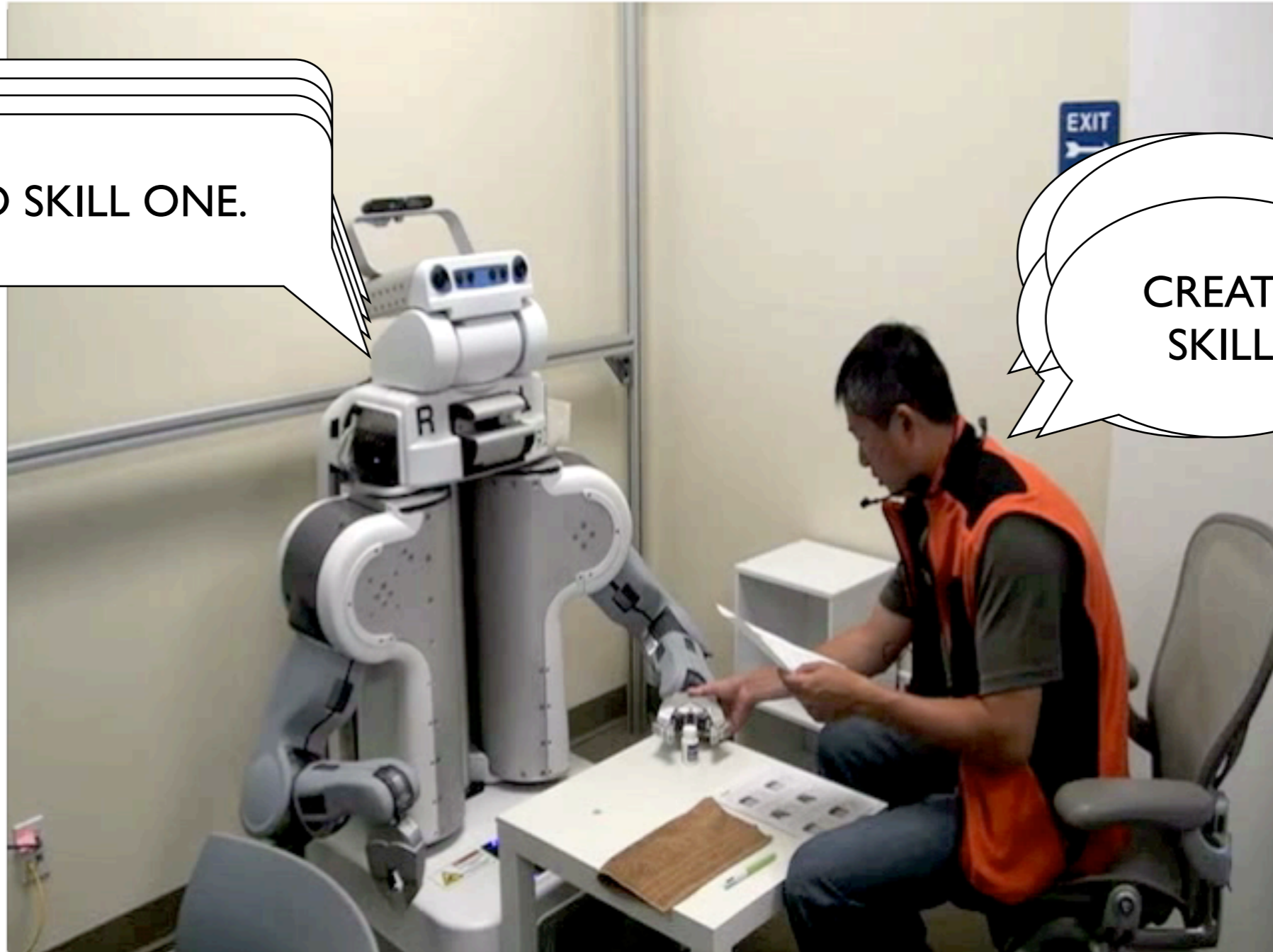


# INTERACTION DESIGN

appropriate **feedback** reduces learning load

CREATED SKILL ONE.

CREATE SKILL



# INTERACTION DESIGN

---

choice of **distinct lexicon** is crucial



Mistake made by 24/30 participants at least once!

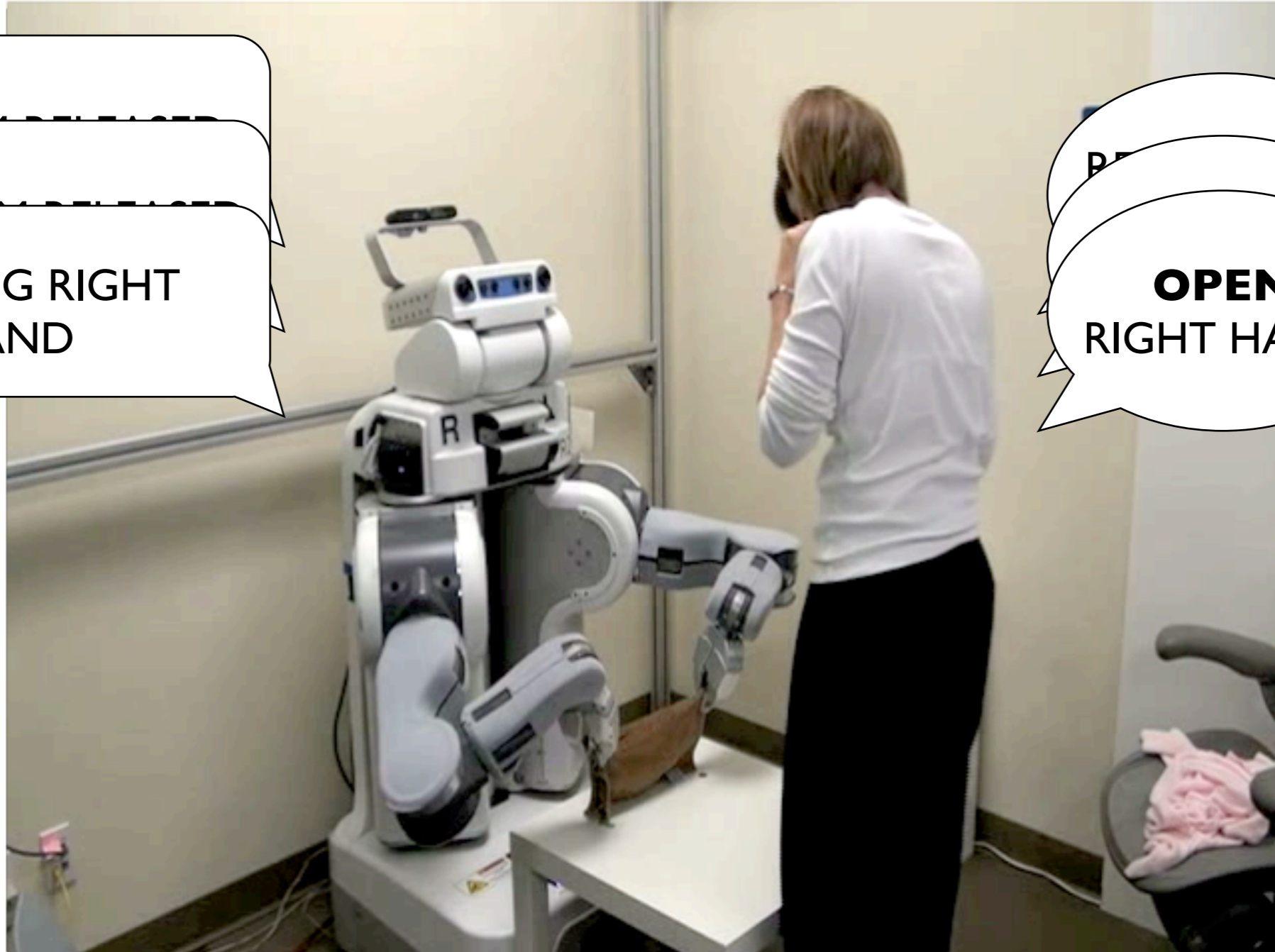


# INTERACTION DESIGN

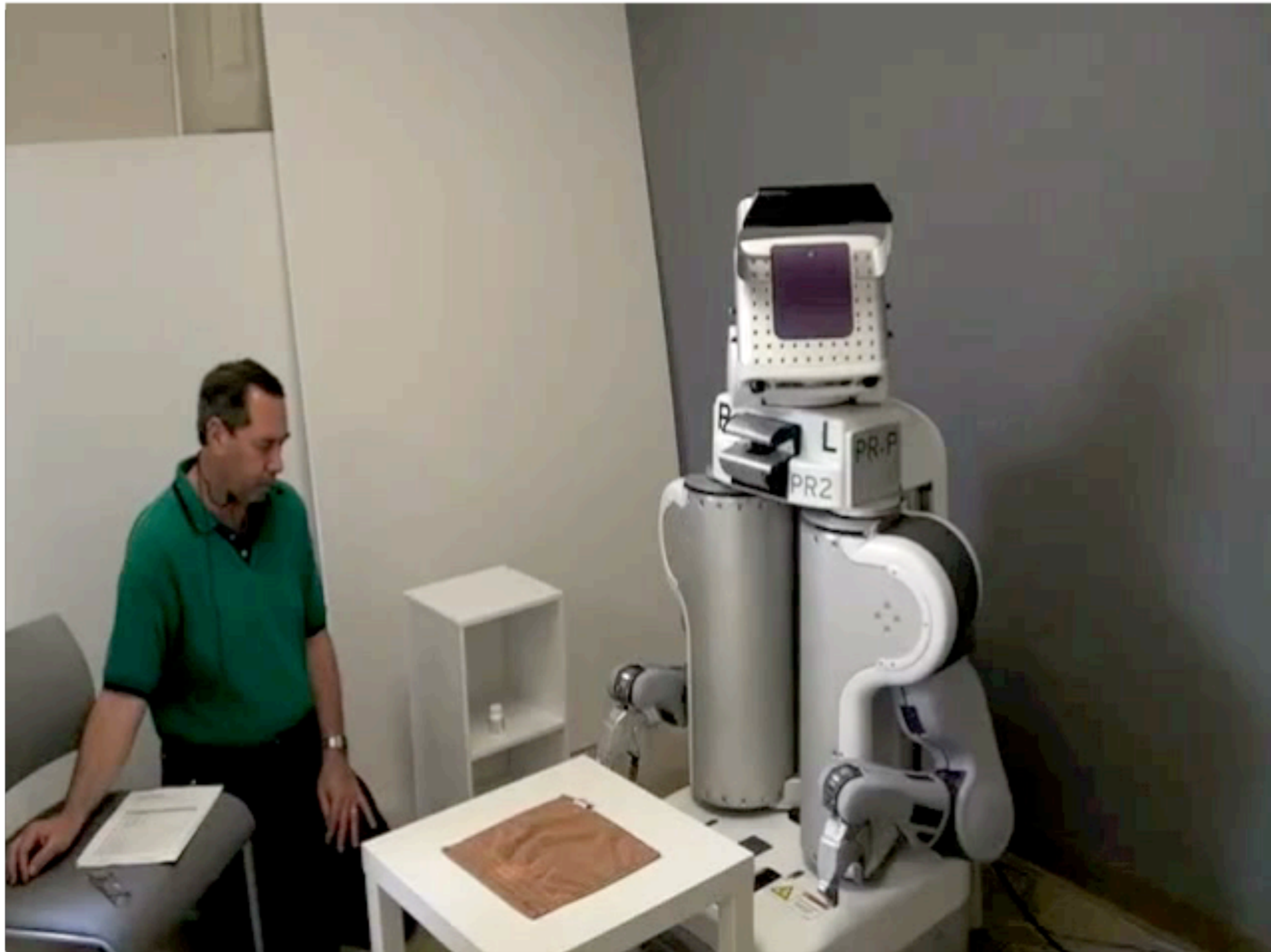
choice of **distinct lexicon** is crucial

OPENING RIGHT  
HAND

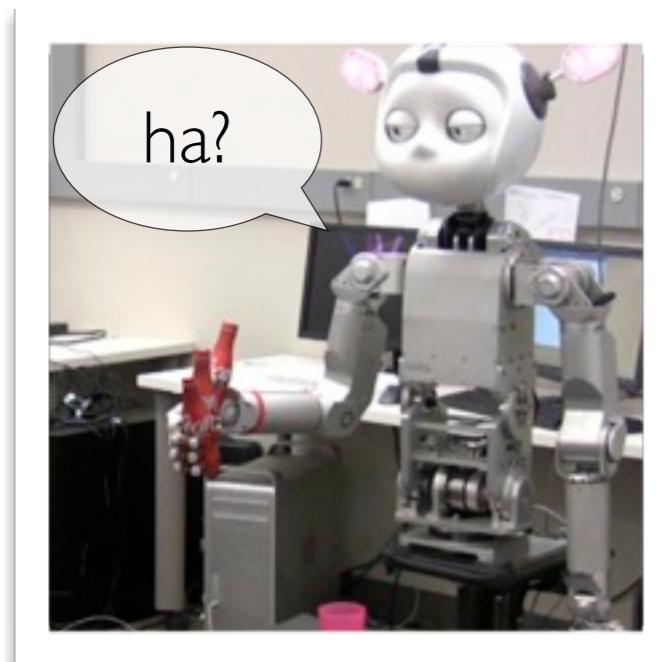
OPEN  
RIGHT HAND



# USER VARIABILITY



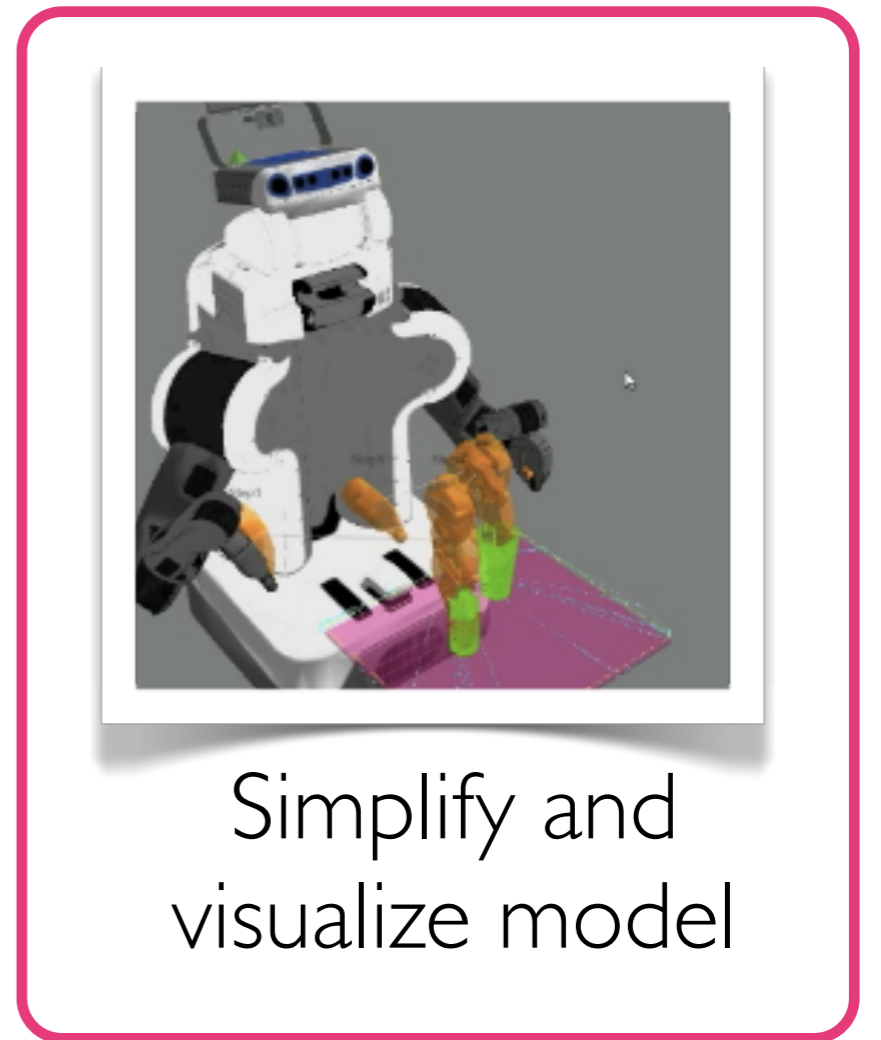
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Make robot  
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Instruct or  
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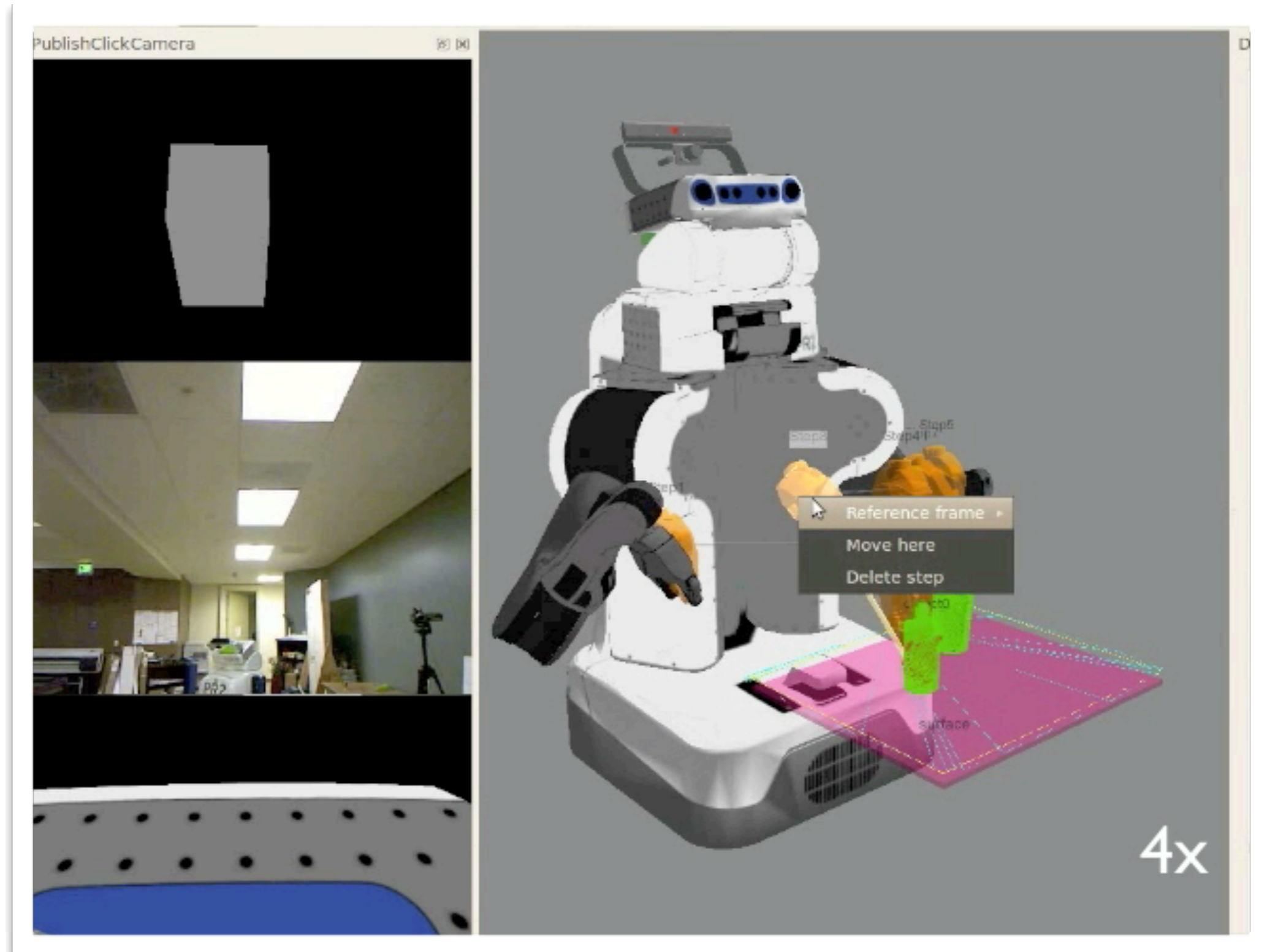
Simplify and  
visualize model



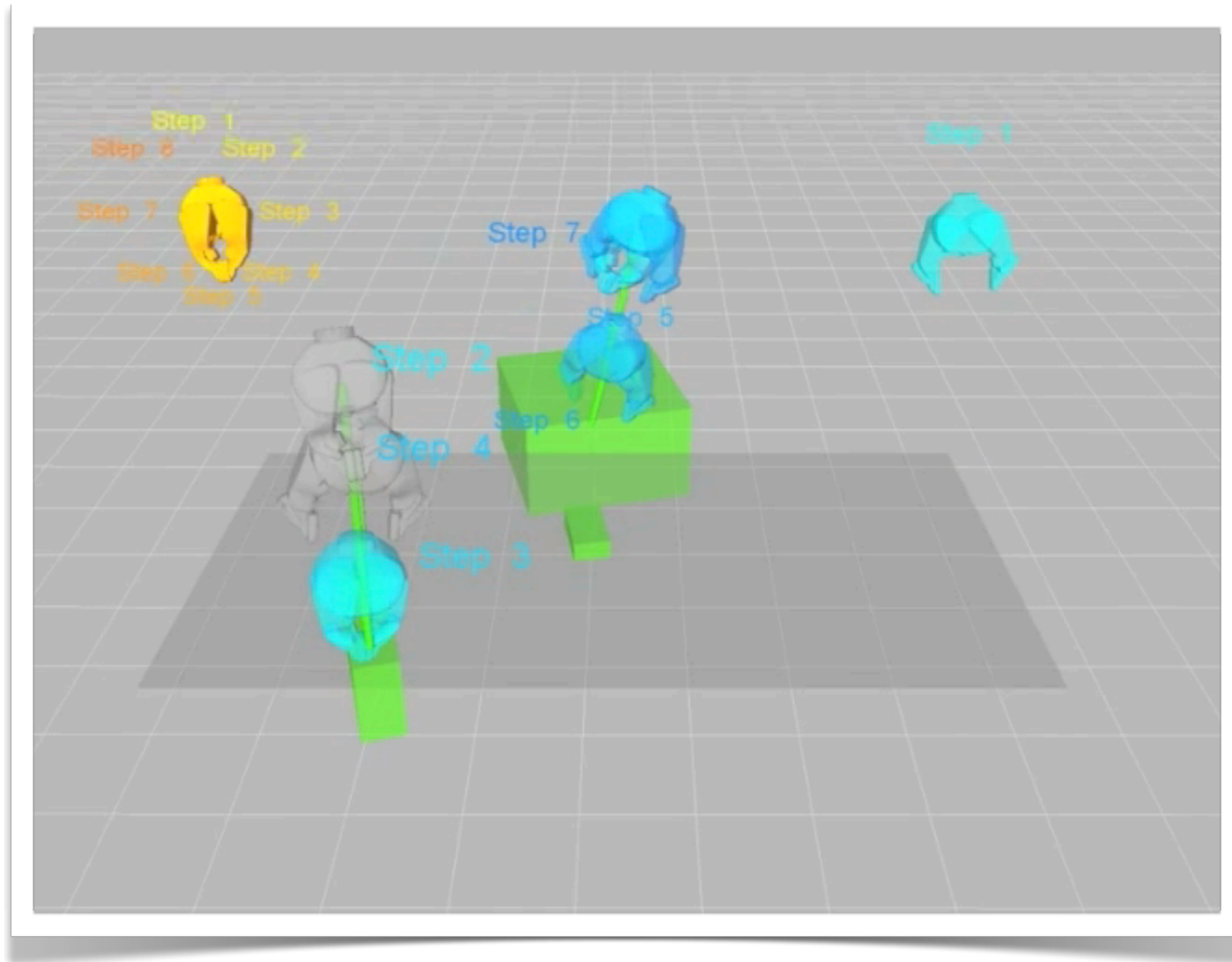
# ONE-SHOT ACTION PROGRAMMING



# INTERACTIVE VISUALIZATION

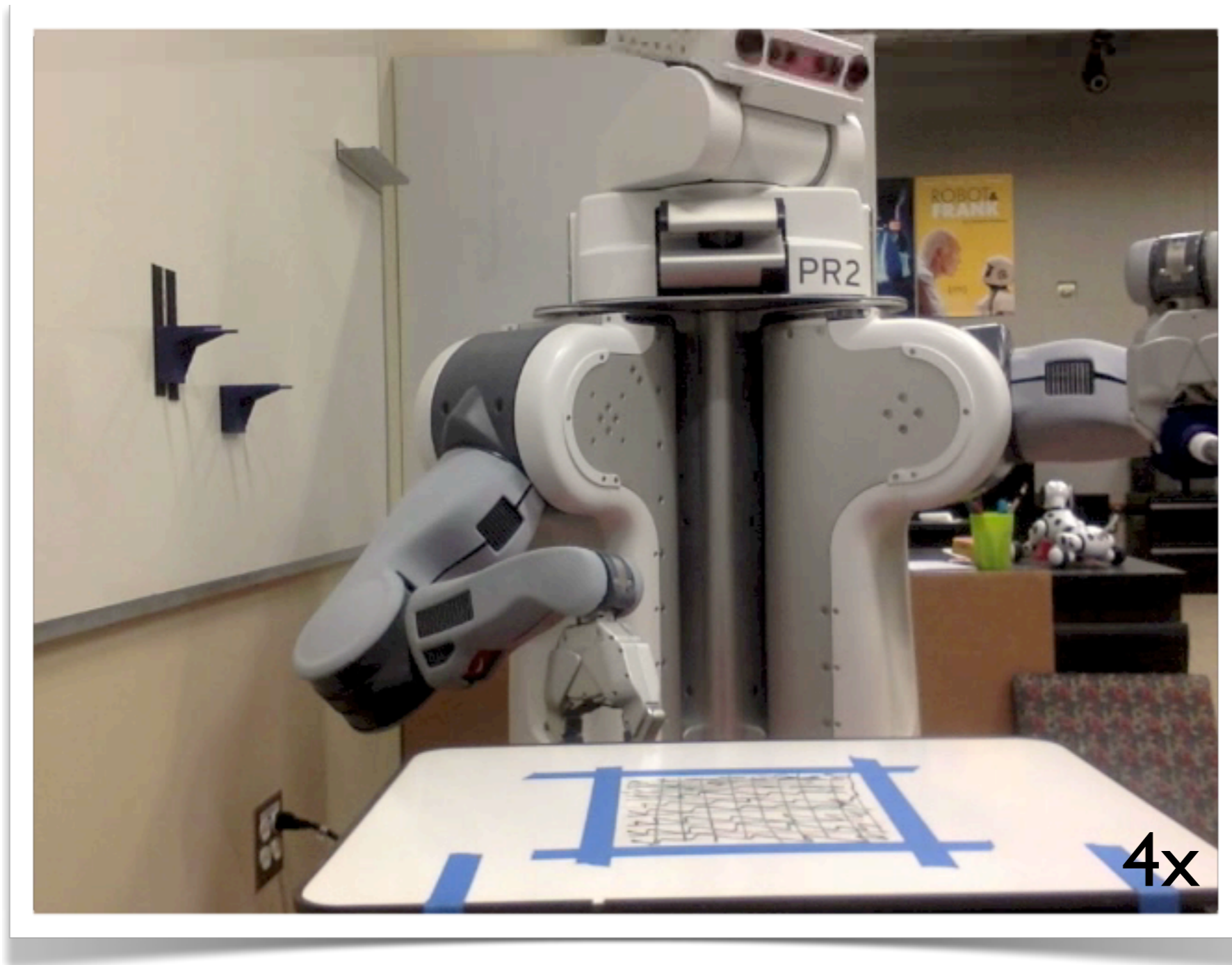


# ACTIVE LEARNING WITH THE CROWD





# SUMMARY: USEFUL & USABLE ROBOTS





# DISCUSSION

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How is HRI different from HCI?  
>>What is a robot?

# AGENCY & INTENTIONALITY

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<https://www.youtube.com/watch?v=76p64j3HINg>

[Heider & Simmel, 1944]

# DISCUSSION

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How is HRI different from HCI?

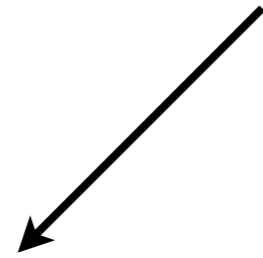
>>What is a robot?

What does that imply for studying HRI?

Should robots exploit being perceived as agents?

# METHODS IN HCI

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**Discovery**

pre-design  
(formative)



**Evaluation**

during/post-design  
(summative)

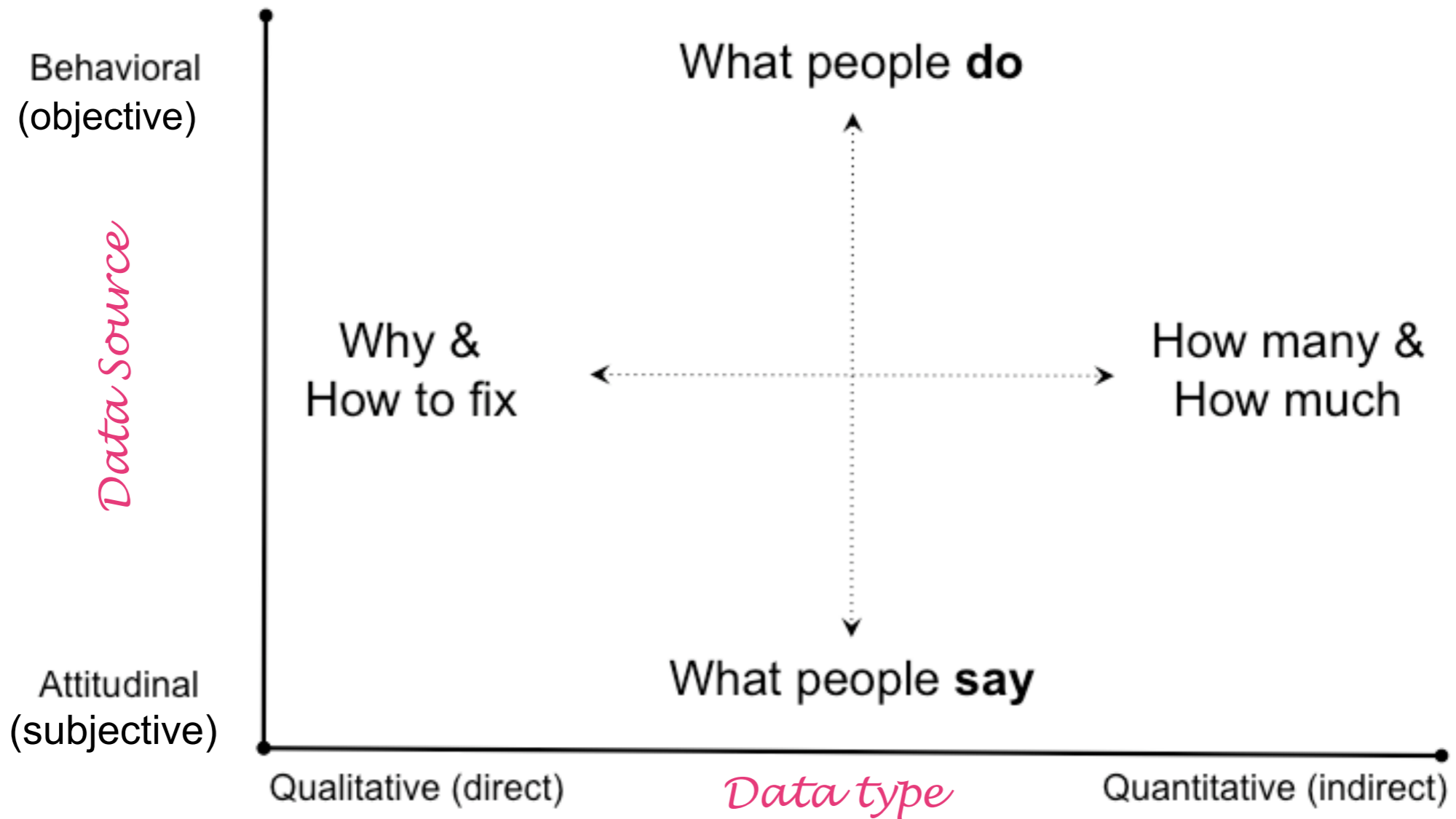


# METHODS

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- Asking **users**
  - Questionnaires, interviews, focus groups, contextual inquiry
- Observing **users**
  - Passive observation, empirical user studies, think-aloud protocol, ethnography, field studies
- Make **users** observe themselves
  - Diaries, experience sampling
- Ask **experts**
  - Heuristic evaluation, cognitive walkthrough

# DATA OBTAINED



# HRI EXAMPLES

---

- Asking **users**

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# SURVEYS

---

- Ju & Takayama. **Should Robots or People Do These Jobs? A Survey of Robotics Experts and Non-Experts About Which Jobs Robots Should Do.** IROS 2011.
- Lee & Sabanovic. **Culturally variable preferences for robot design and use in South Korea, Turkey, and the United States.** HRI 2014.



# CONTEXTUAL INQUIRY

- Pantofarou et al. **Exploring the Role of Robots in Home Organization.** HRI 2012.



**Figure 1: Storage areas seen in informants' homes. These are the dark, cluttered and variable spaces that a robot tasked with organization will face.**

# HRI EXAMPLES

---

- Asking **users**

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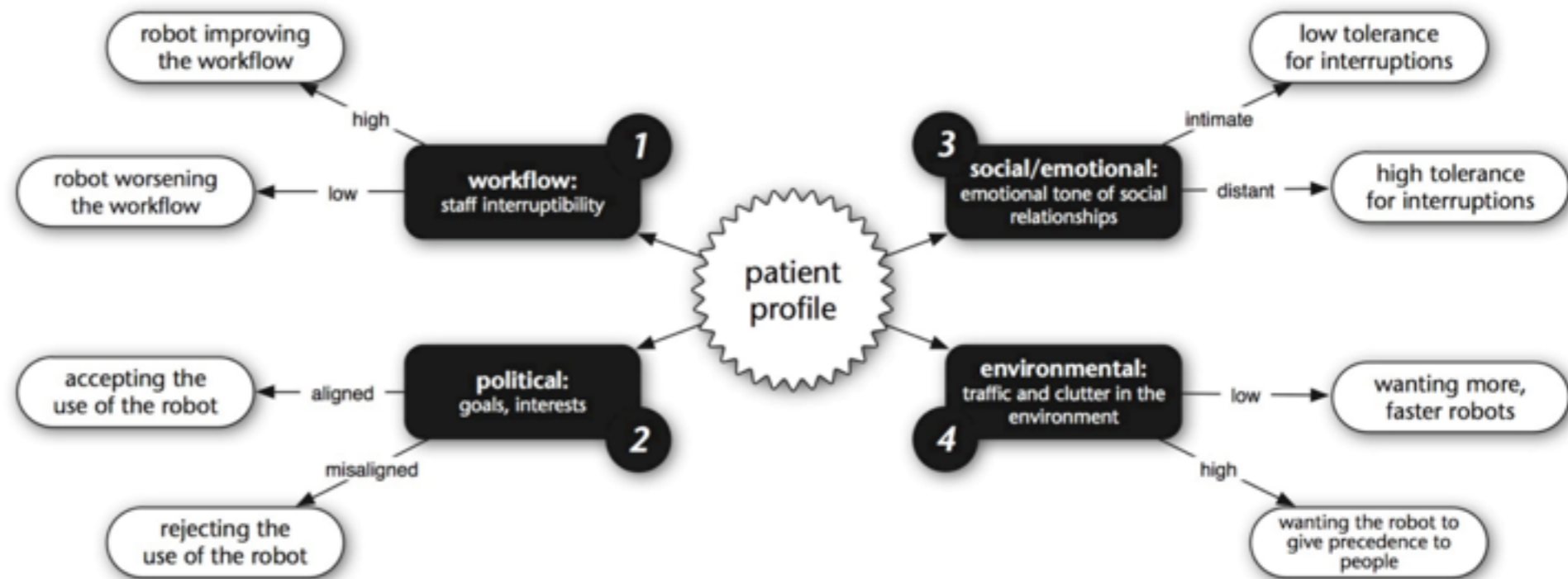
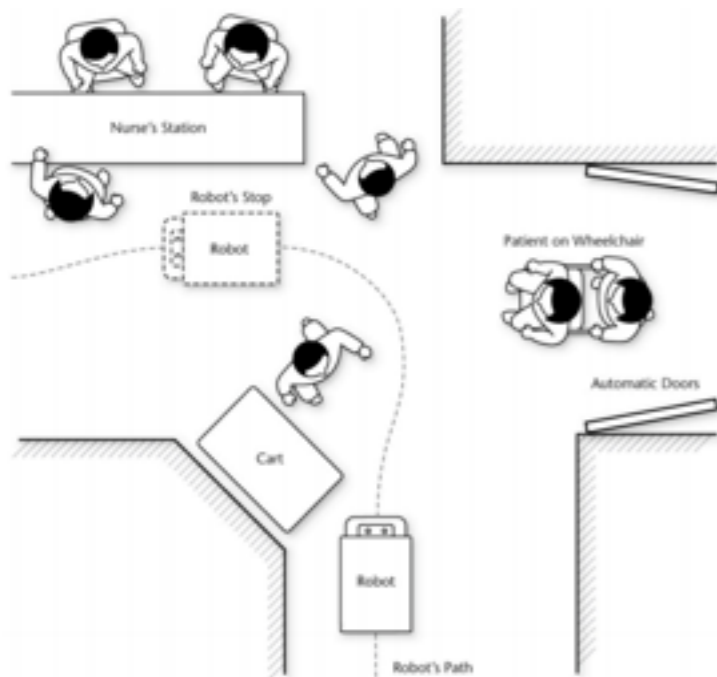
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- Ask **experts**

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# ETHNOGRAPHY

- Mutlu & Forlizzi. **Robots in Organizations: The Role of Workflow, Social, and Environmental Factors in Human-Robot Interaction.** HRI 2008.





# FIELD STUDIES

- Fink et al. **Which Robot Behavior Can Motivate Children to Tidy up Their Toys? Design and Evaluation of “Ranger”, HRI 2014.**



**Figure 3: Children interacting with Ranger during the field study: The robot’s eyes received remarkable attention. Left: first moments of a family exploring together the robot; center: two boys putting toys into Ranger, which displays red lights; right: a girl showing a toy to the robot**



# HRI EXAMPLES

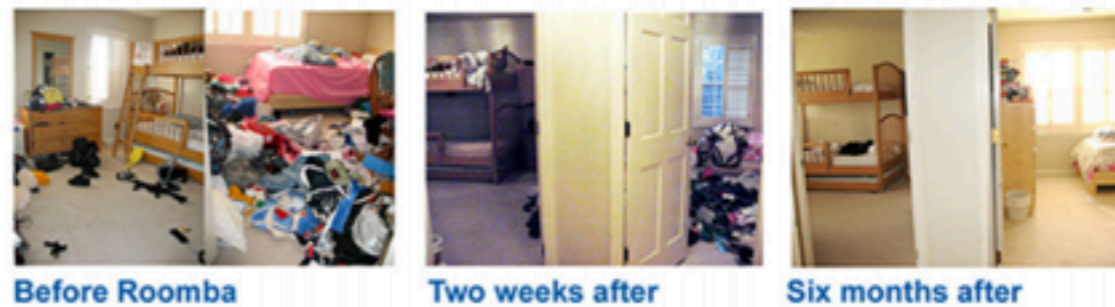
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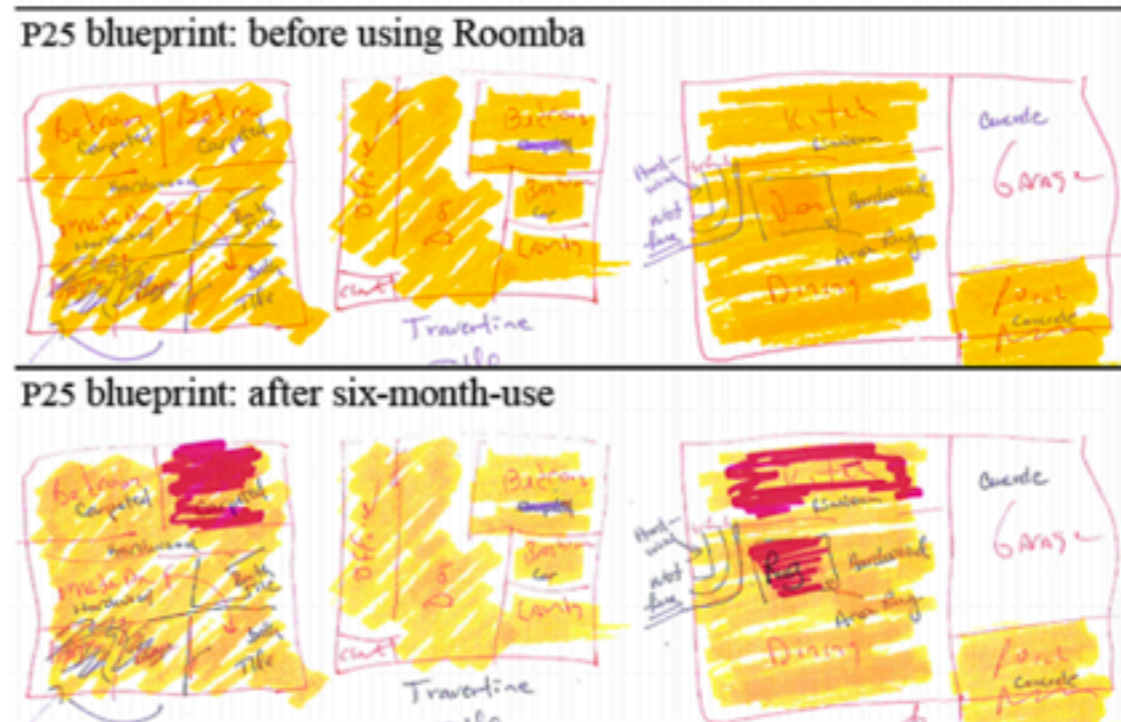
# DIARIES/EXPERIENCE SAMPLING

- Sung et al. **Domestic Robot Ecology: An Initial Framework to Unpack Long-Term Acceptance of Robots at Home**, Journal of social Robotics.

**Fig. 2** Long-term effect of robot usage in P15: the mother described that the robot use motivated her to undertake major cleaning throughout the house. Robots kept the floor clean and clutter-free, and she wanted to keep the rest of the house up to the same standard



**Fig. 3** Above: P25 highlighted entire home as expected areas for Roomba use. Below: P25 localized cleaning areas as highlighted in red after six months



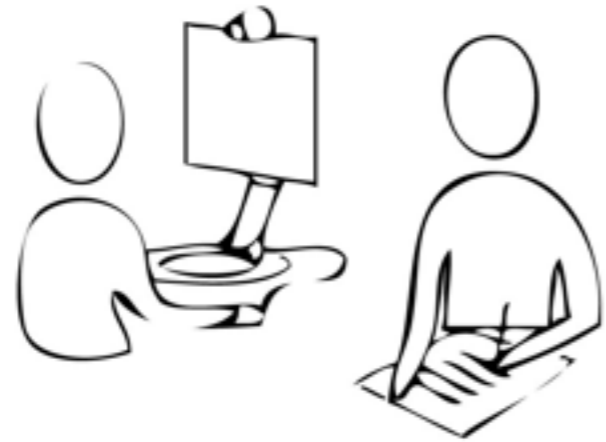
# HRI EXAMPLES

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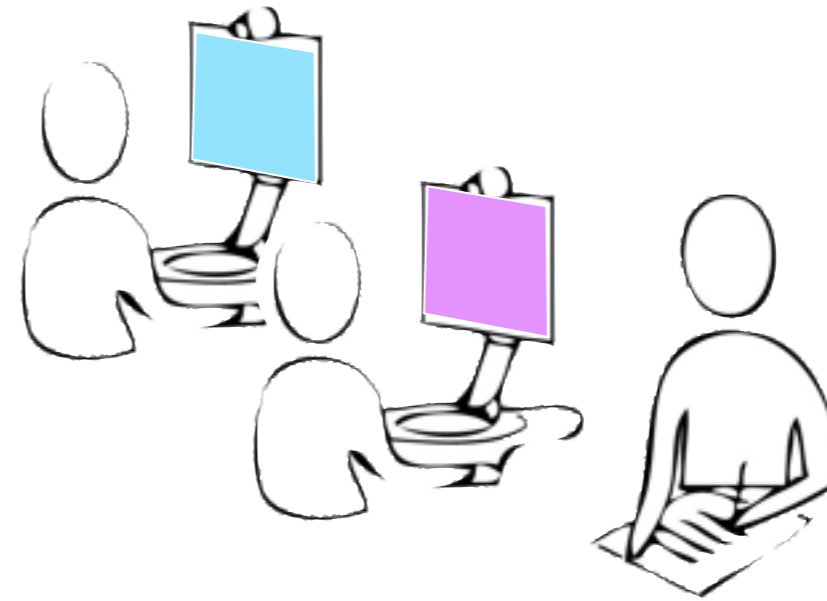
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# OBSERVING INTERACTION

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Passive observation



Comparative study



# DIARIES/EXPERIENCE SAMPLING

- Cakmak & Takayama. **Teaching people how to teach robots: The effect of instructional materials and dialog design, HRI 2014.**

Passive observation

Comparative study

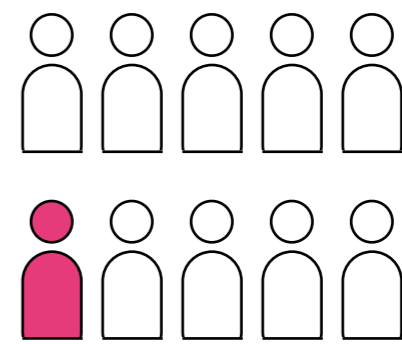
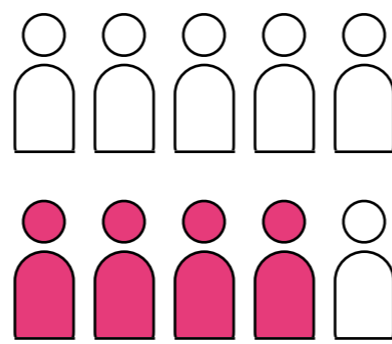
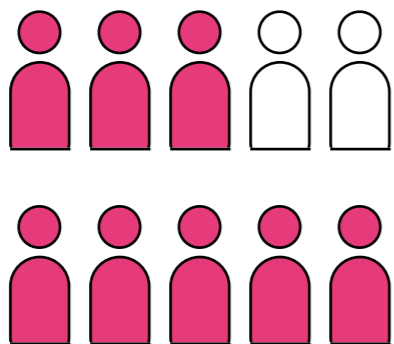


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↙  
Comparative study

number of participants who requested tech support



BASELINE



TUTORIAL



VIDEO

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- Cakmak & Takayama. **Teaching people how to teach robots: The effect of instructional materials and dialog design**, HRI 2014.



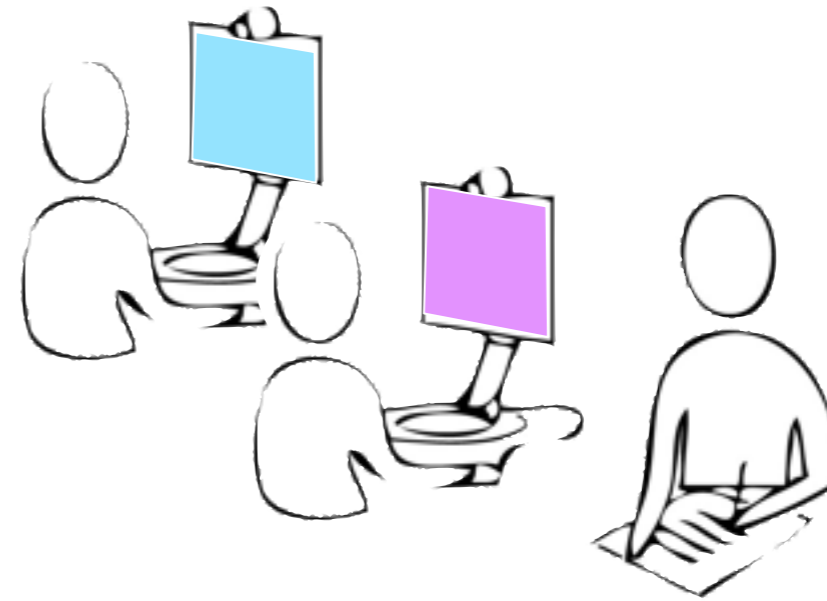
Passive observation

appropriate **feedback** reduces learning load

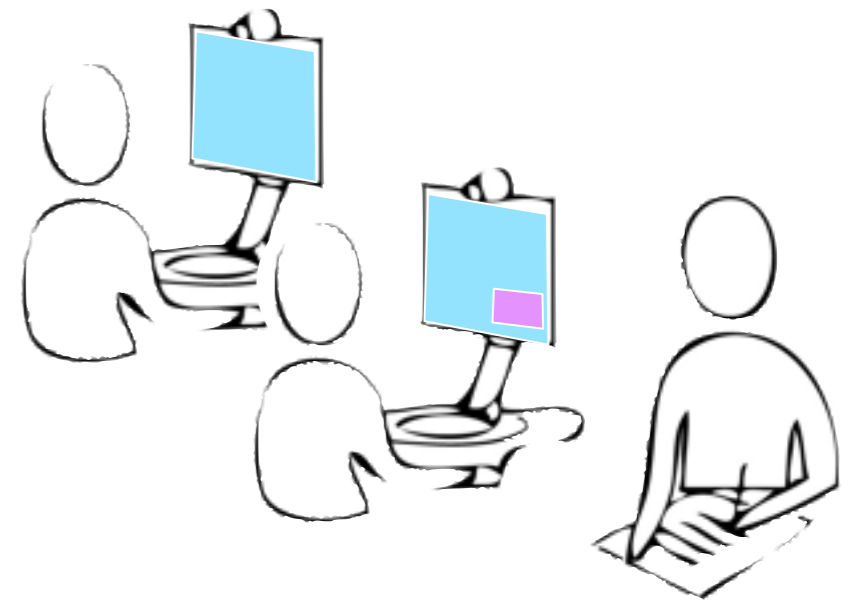
choice of **distinct lexicon** is crucial

# EMPIRICAL USER STUDIES

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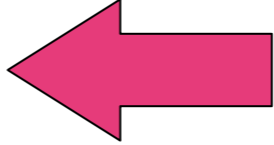
Comparative study



A-B testing

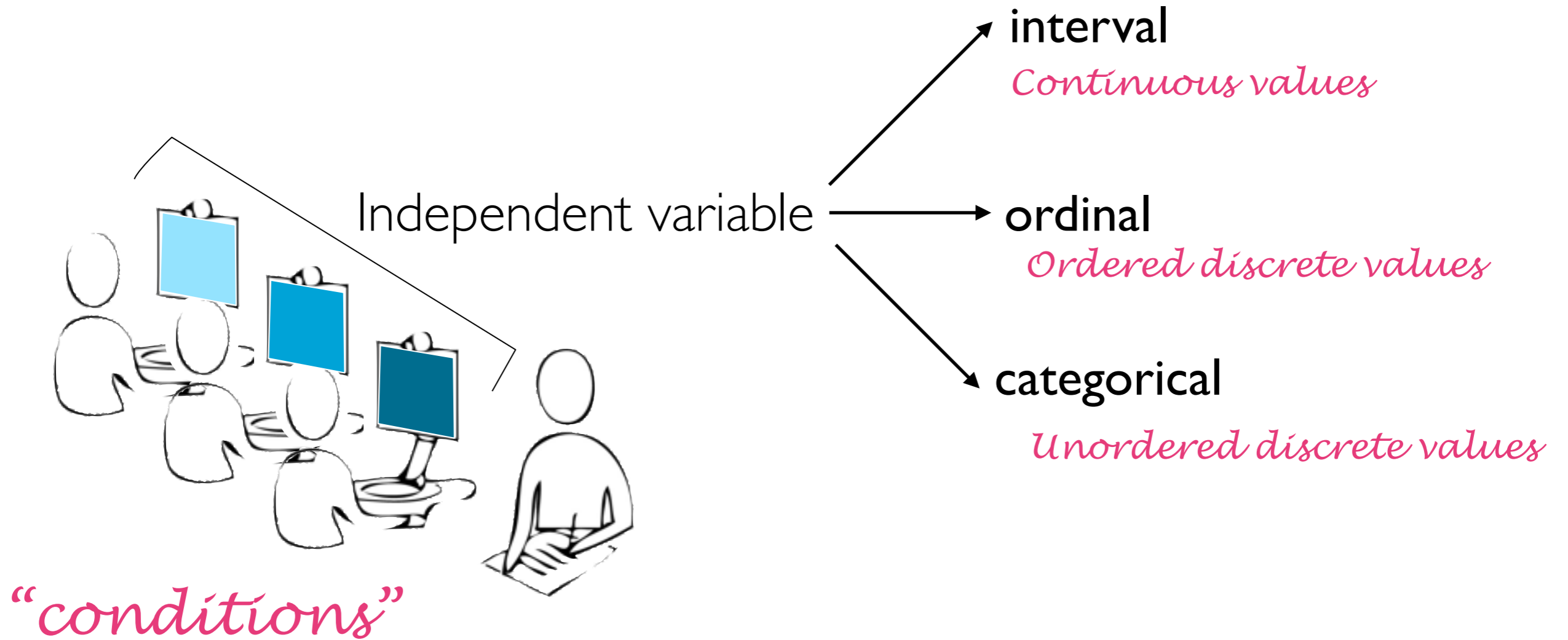
# EMPIRICAL USER STUDIES

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- What is being compared? 
- Independent variables
- What are they being compared in?
- Dependent variables (“metrics”)
- What (else) is being varied?
- (What is kept constant?)
- Extraneous variables

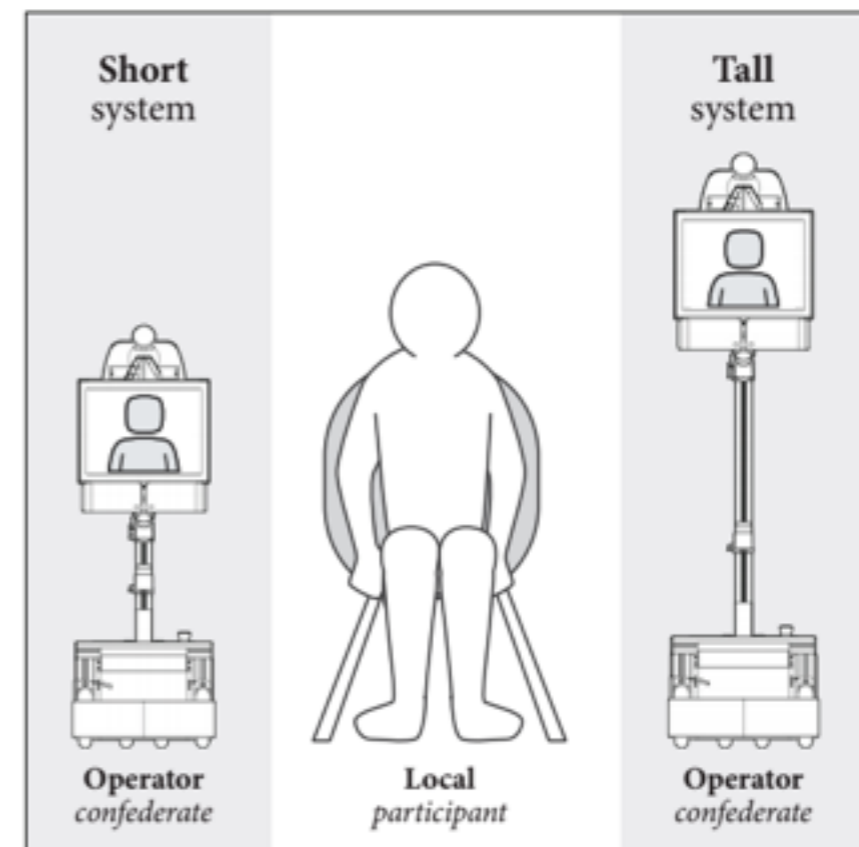
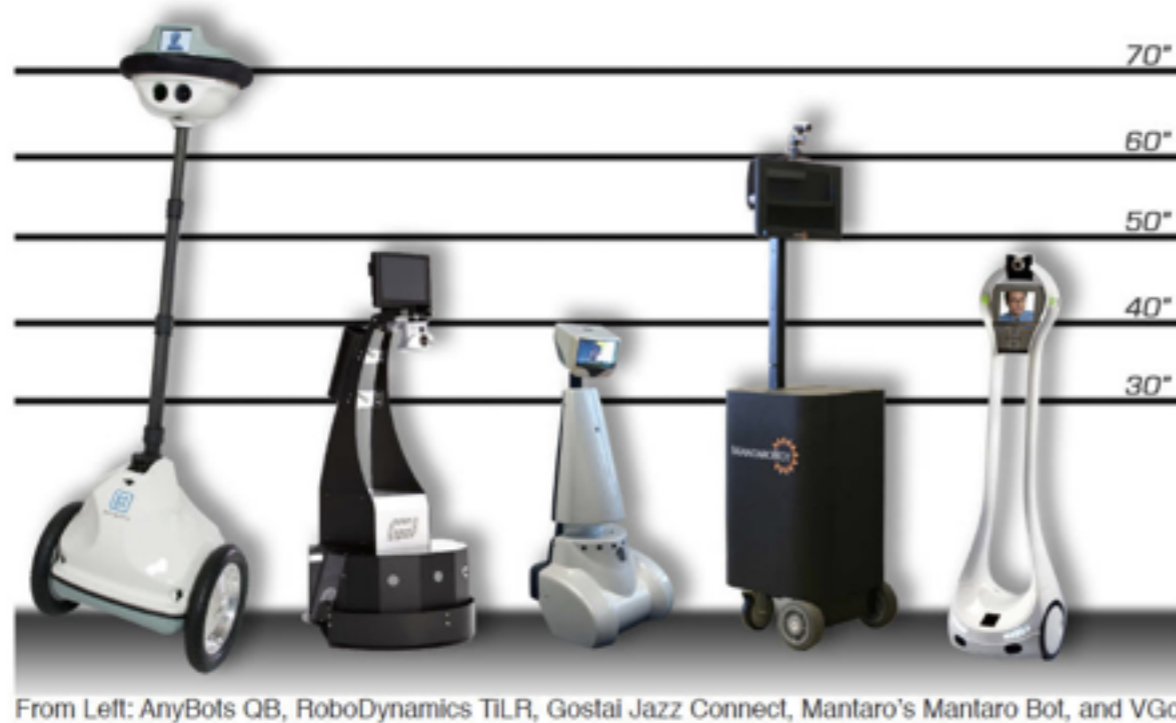


# EMPIRICAL USER STUDIES



# WHAT IS BEING COMPARED?

- Example: **Interval** independent variable
  - What is the effect of **height** on telepresence systems?



[Rae, Takayama & Mutlu, 2013]

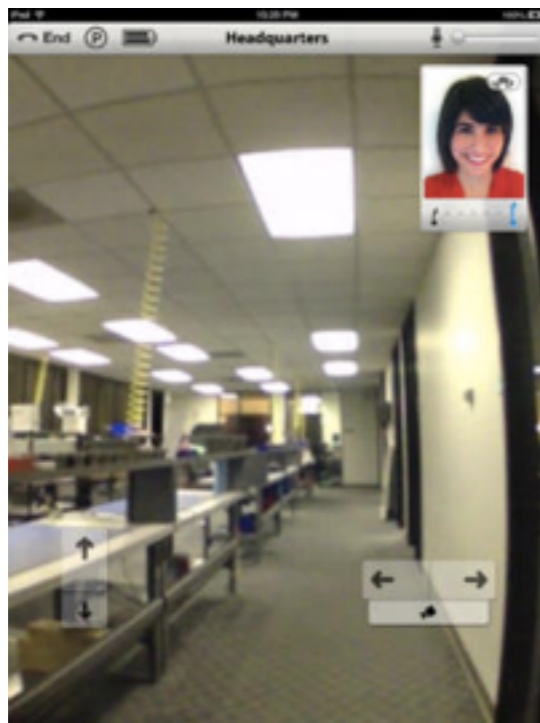
# WHAT IS BEING COMPARED?

---

- Example: **Ordinal** independent variable
  - What is the effect of **educational background** on acceptance of robots in the workplace?

# WHAT IS BEING COMPARED?

- Example: **Categorical** independent variable
  - What is the effect of **input modality** on telepresence systems?



– keyboard

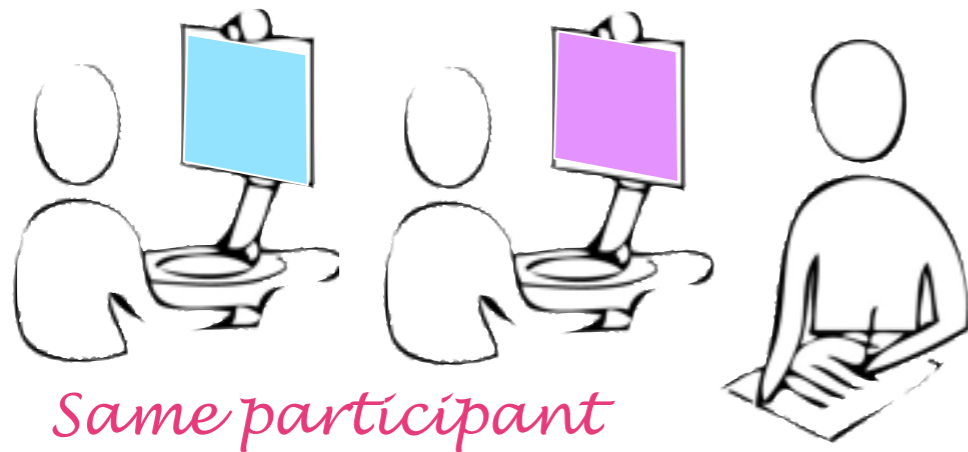


– mouse



– joystick

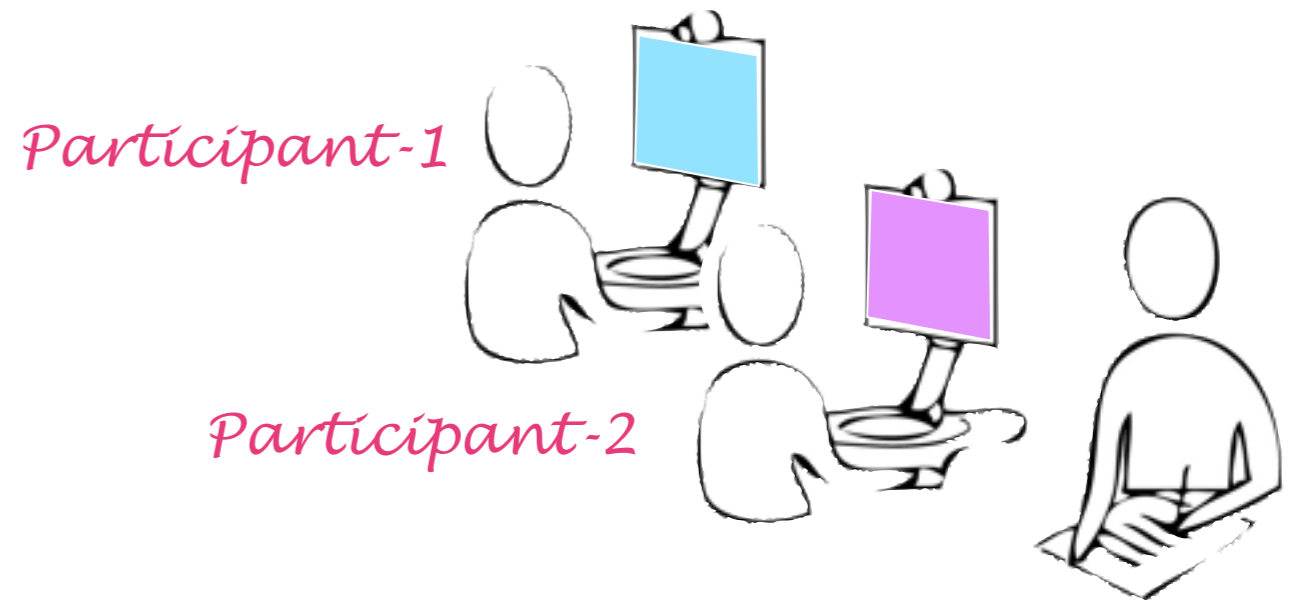
# WITHIN -VS- BETWEEN



within

- + allows comparison
- + requires less participants
- subject to ordering effects

> Order counterbalancing

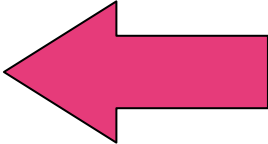


between



# EMPIRICAL USER STUDIES

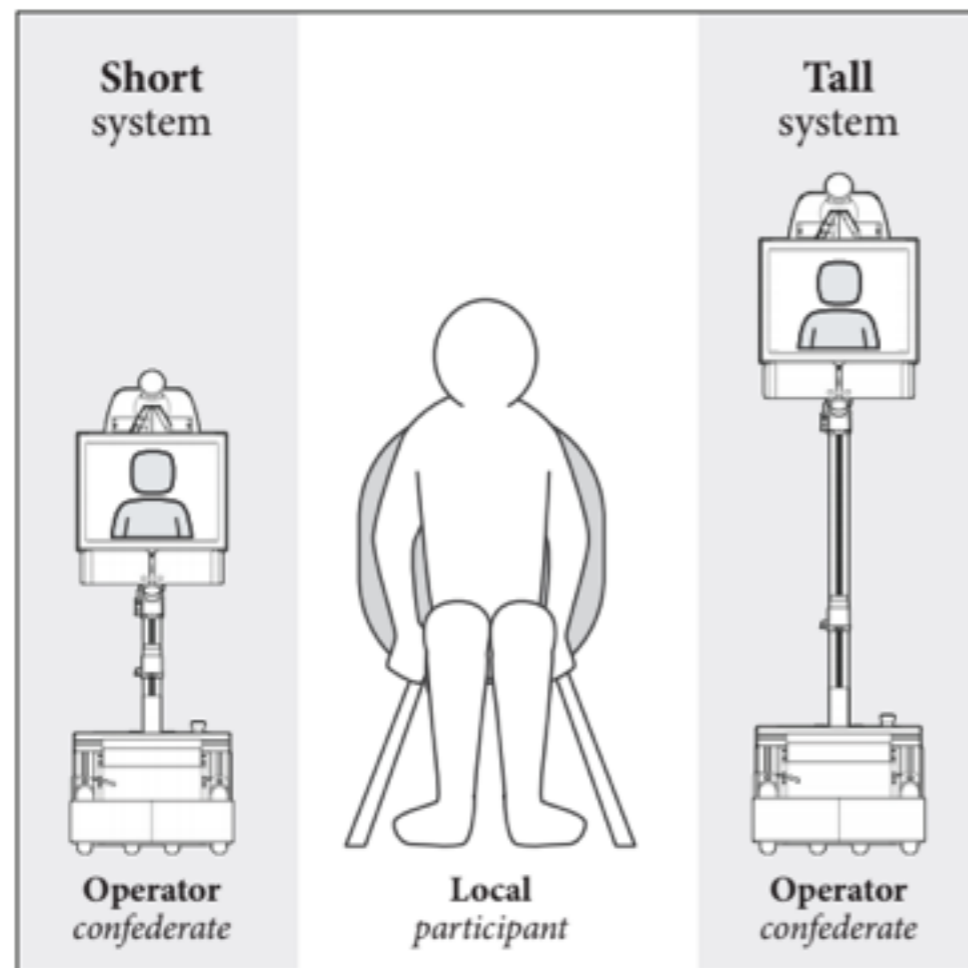
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- What is being compared?
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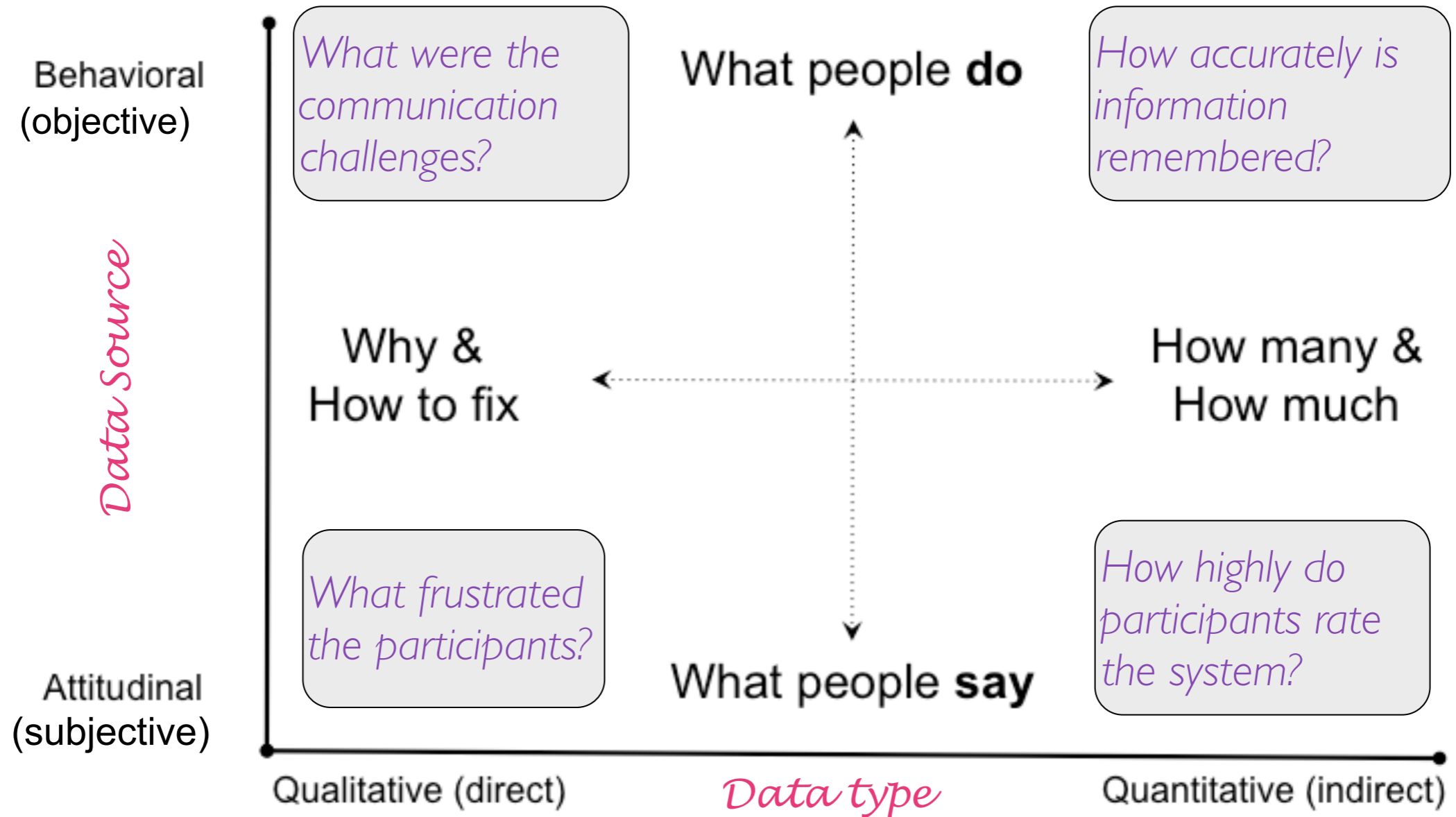
# INDEPENDENT VS. DEPENDENT VARS

- Example:
  - What is the effect of height on telepresence systems?

*in terms of what?*



# WHAT TO MEASURE/OBSERVE?

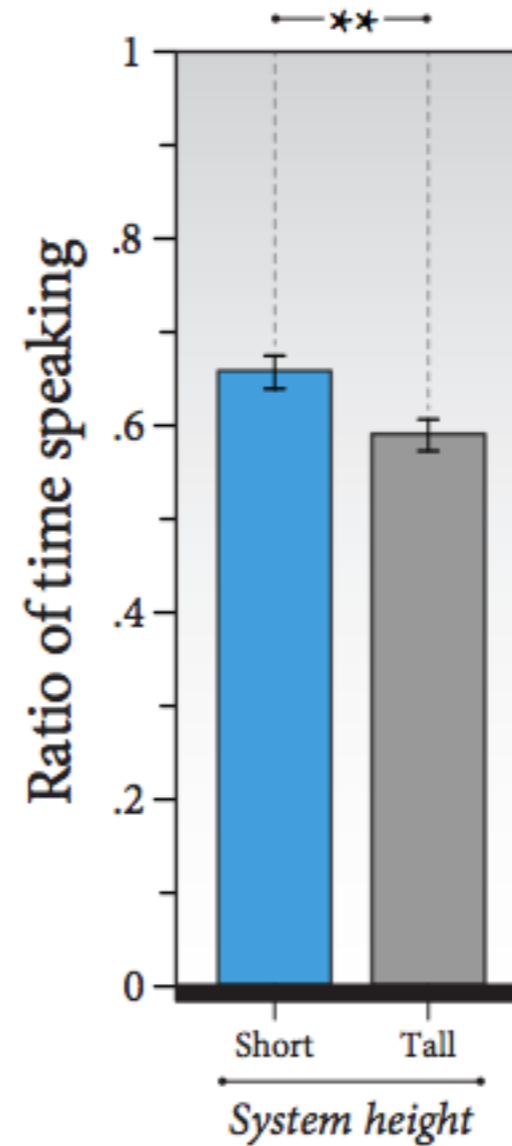
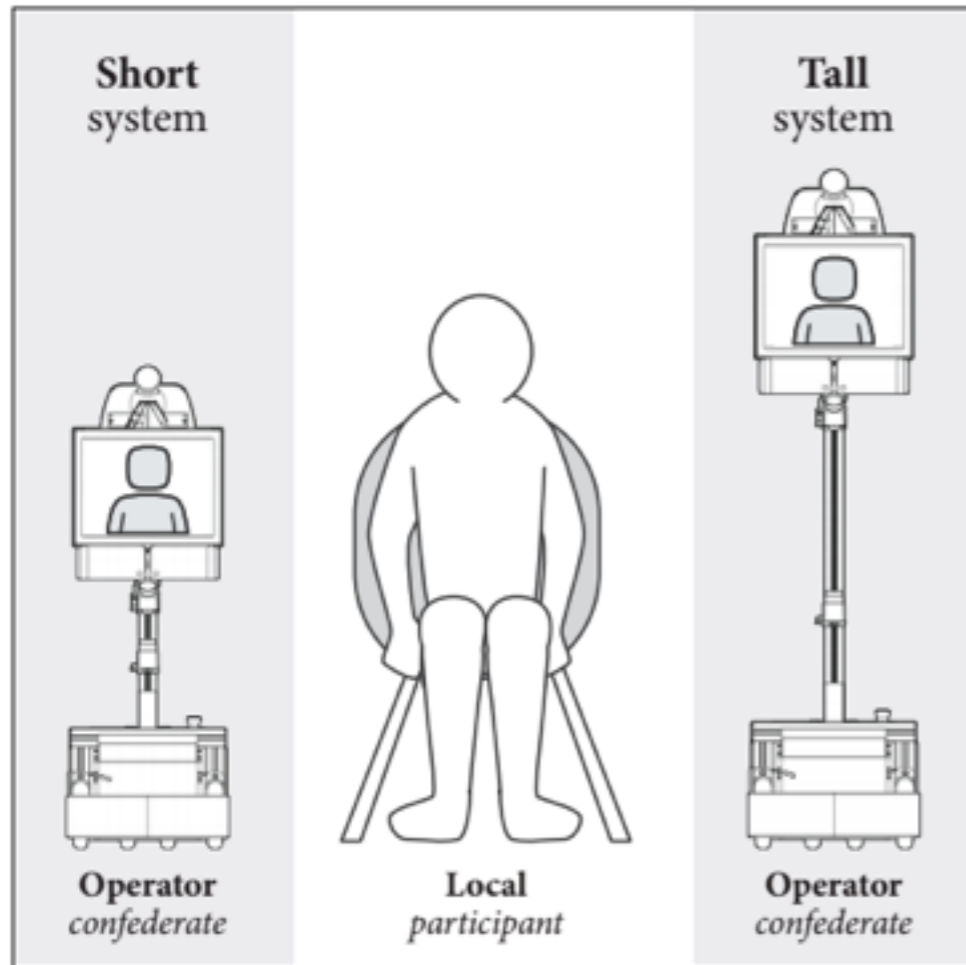


# WHAT TO MEASURE/OBSERVE?

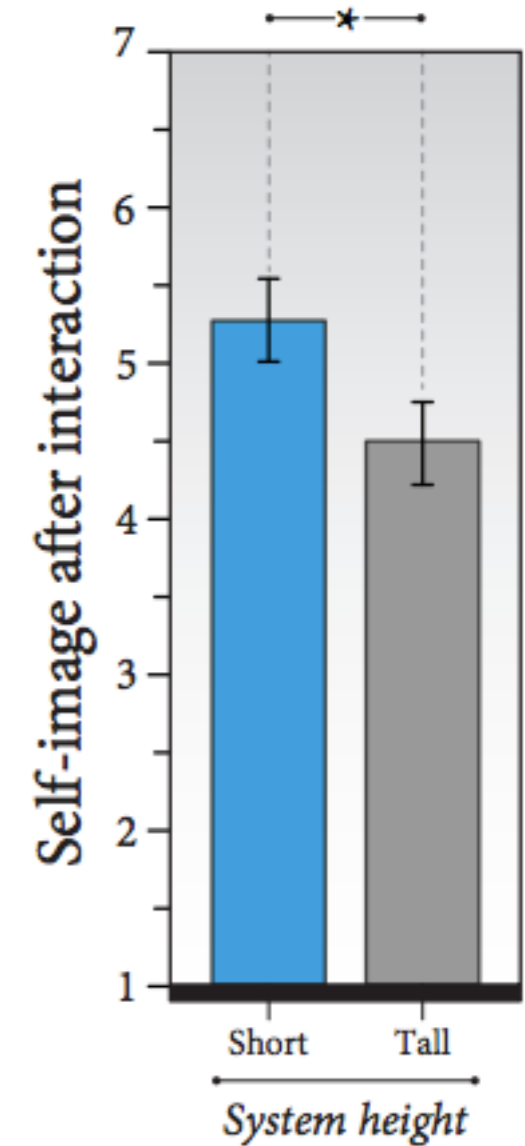
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- Effectiveness (e.g. accuracy, # of errors, engagement/compliance)
- Efficiency (e.g. time to complete)
- Effort (e.g. mental load)

# DEPENDENT VARIABLES



*what people do..*

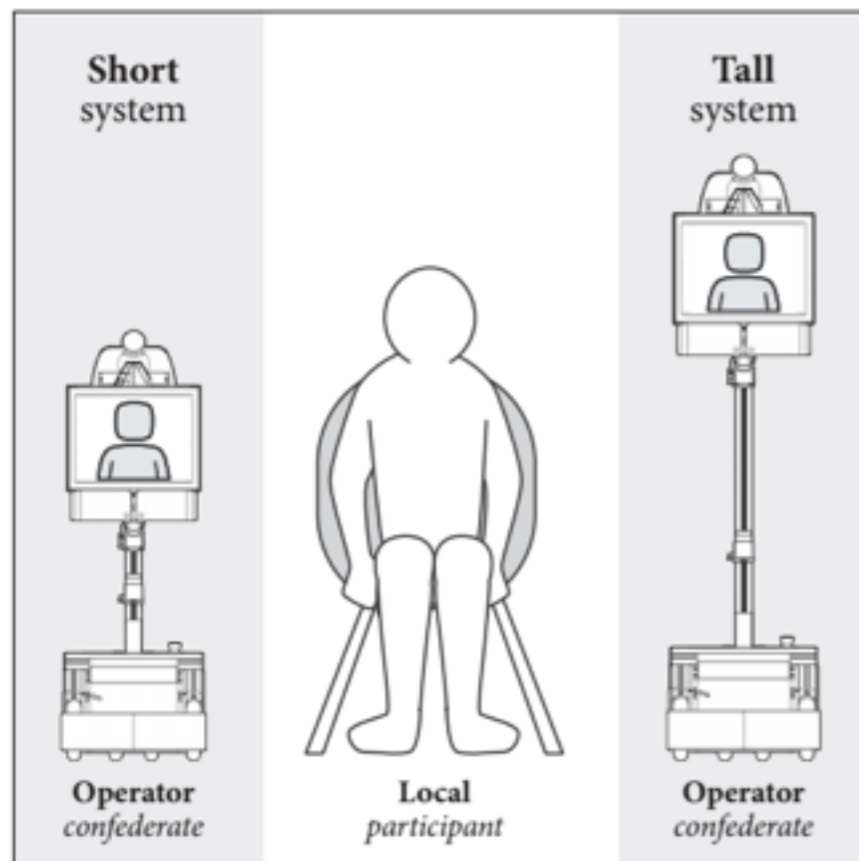


*what people say..*



# WHAT IS BEING MEASURED?

- Example: **Interval** dependent variable
  - What is the effect of height on conversation control?

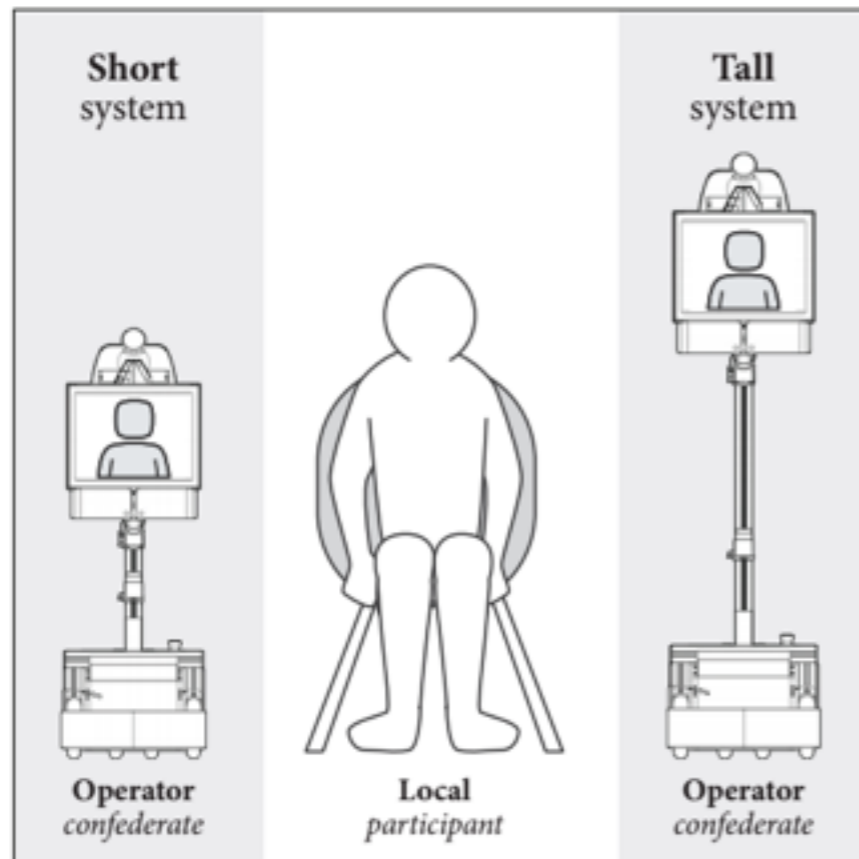


- ratio of time speaking
- ratio of decisions influenced
- self assessment of control
- ...

# WHAT IS BEING MEASURED?

- Example: **Ordinal** dependent variable
- What is the effect of height on user preference?

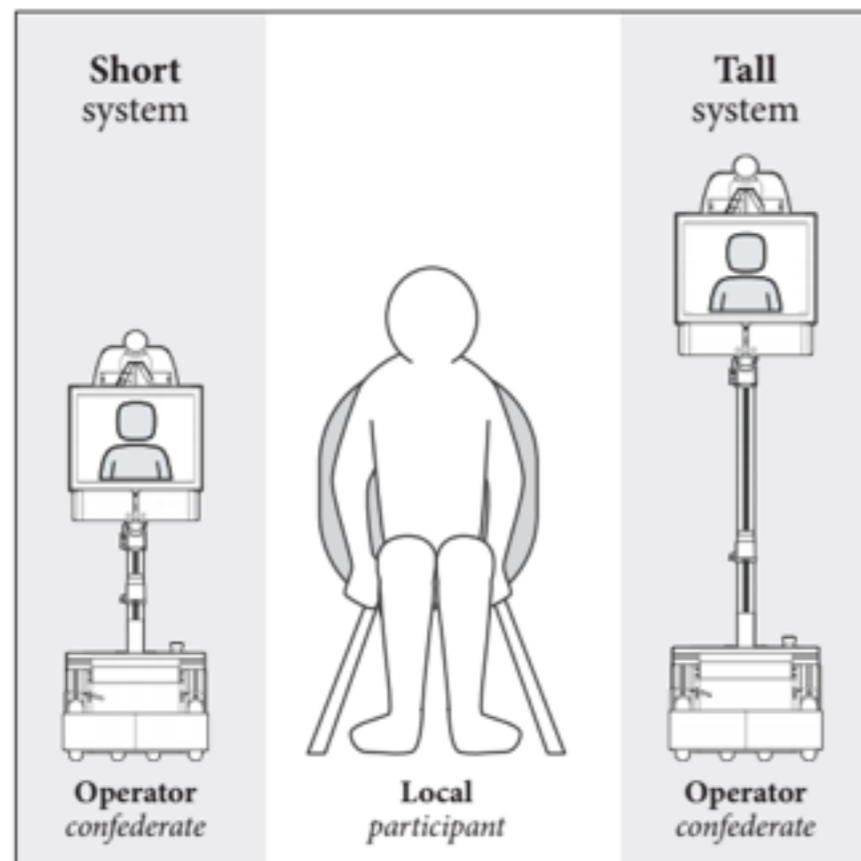
-user rating of the system



★☆☆☆☆	Hated it.
★★☆☆☆	Hated it.
★★★☆☆	Ashamed of liking it.
★★★★☆	Loved it.
★★★★★	Claimed to love it, but was actually a little bored.

# WHAT IS BEING MEASURED?

- Example: **Categorical** dependent variable
  - What is the effect of height on conversation control?



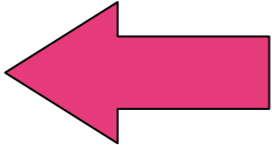
-choose one:

“I felt like the leader”

“I felt like the follower”

# EMPIRICAL USER STUDIES

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- What is being compared?
  - Independent variables
- What are they being compared in?
  - Dependent variables (“metrics”)
- What (else) is being varied? 
- (What is kept constant?)
  - Extraneous variables

# EXTRANEOUS VARIABLES

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- Similar to independent variables but we are not looking for an effect
  - What is the effect of \_\_\_\_\_ on conversation control?
    - things that vary unless you control for them  
*gender, age, background of participants*
    - things that you explicitly vary to demonstrate lack of effect  
*tasks performed using the system*



# INTERPRETING THE RESULTS

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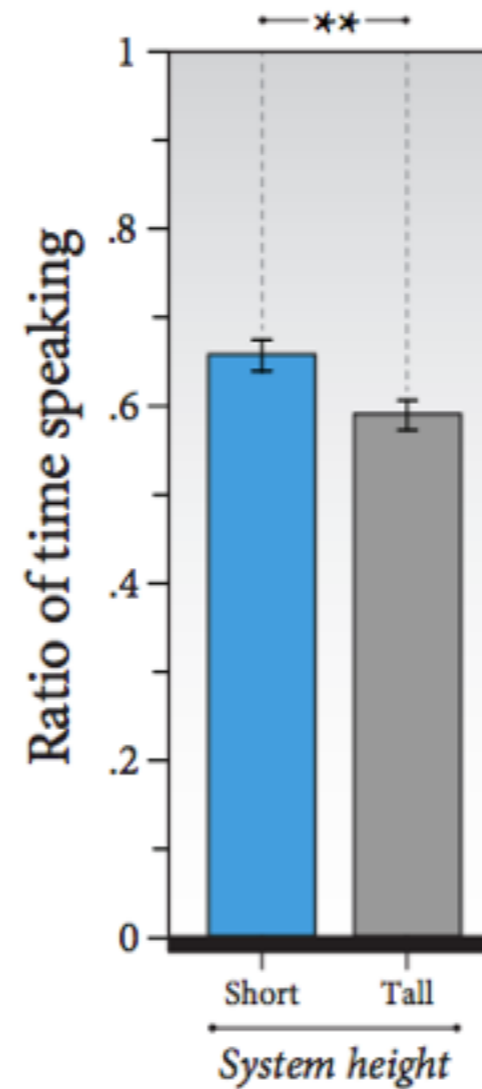
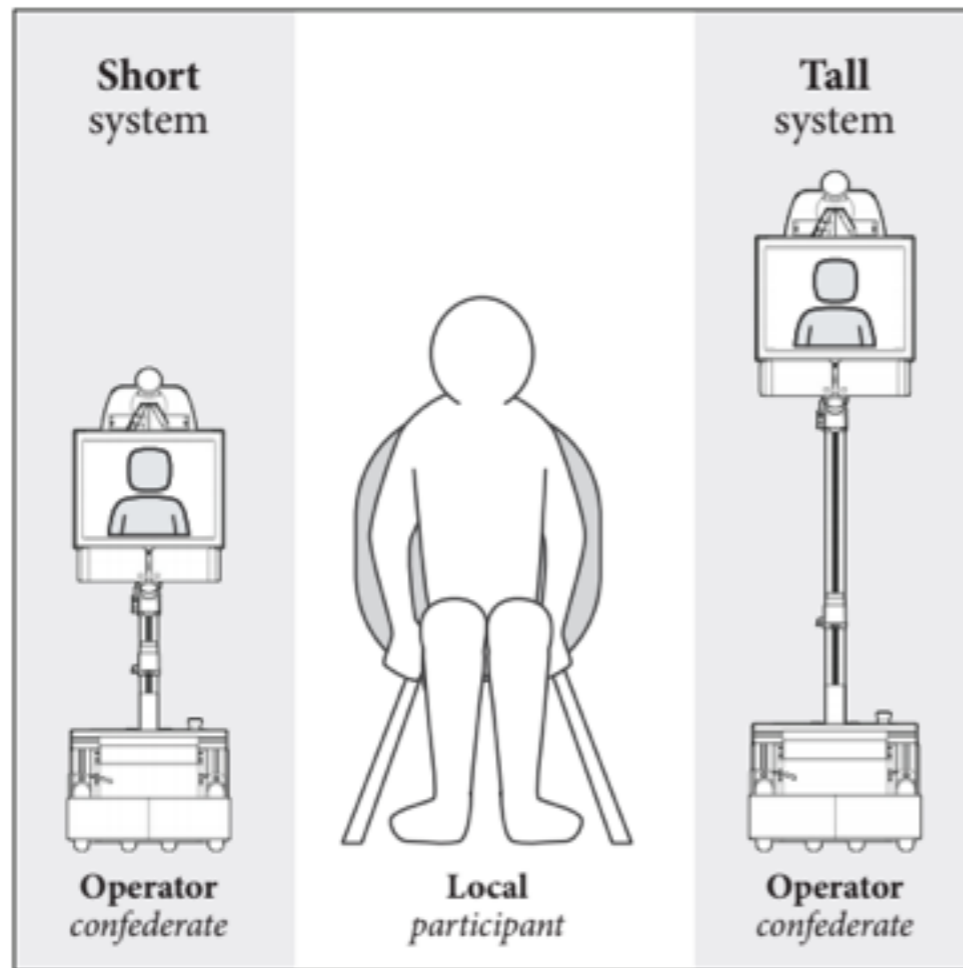
- What is being compared?
  - Independent variables
- What are they being compared in?
  - Dependent variables (“metrics”)

## **Main question:**

Does <independent variable> cause differences in <dependent variable>?

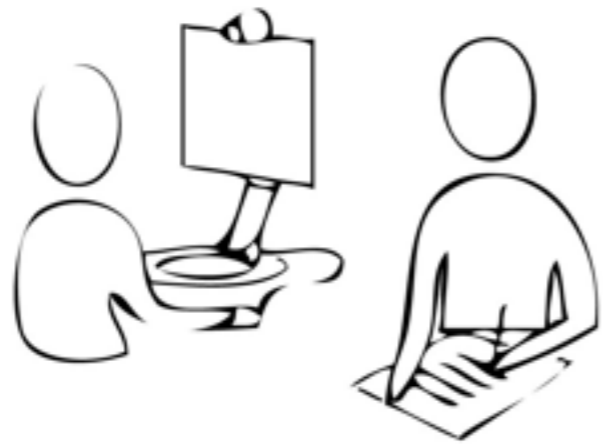
# INTERPRETING THE RESULTS

Does height effect ratio of time speaking?

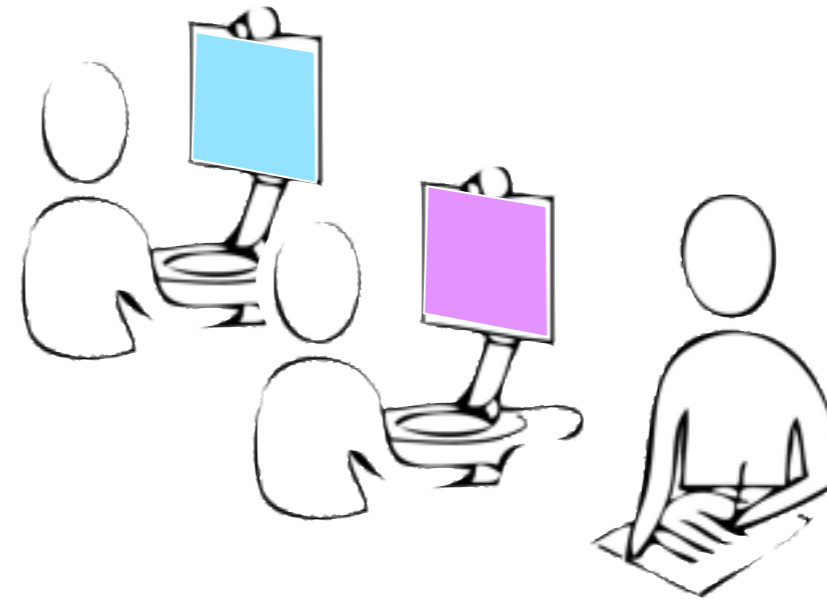


Yes/No?

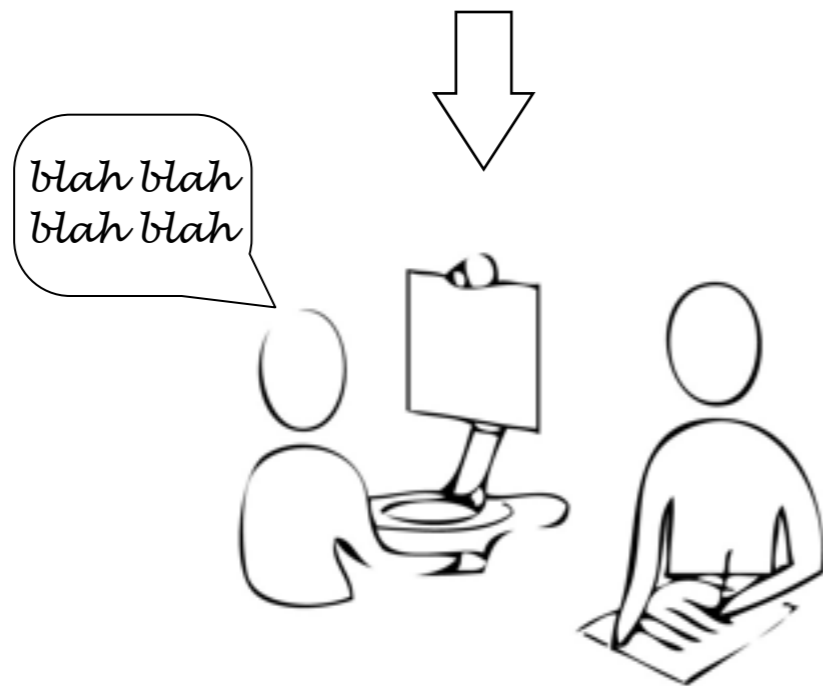
# OBSERVING INTERACTION



Passive observation



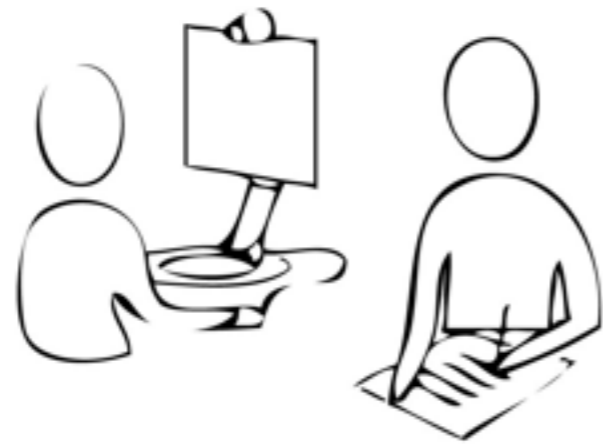
Comparative study



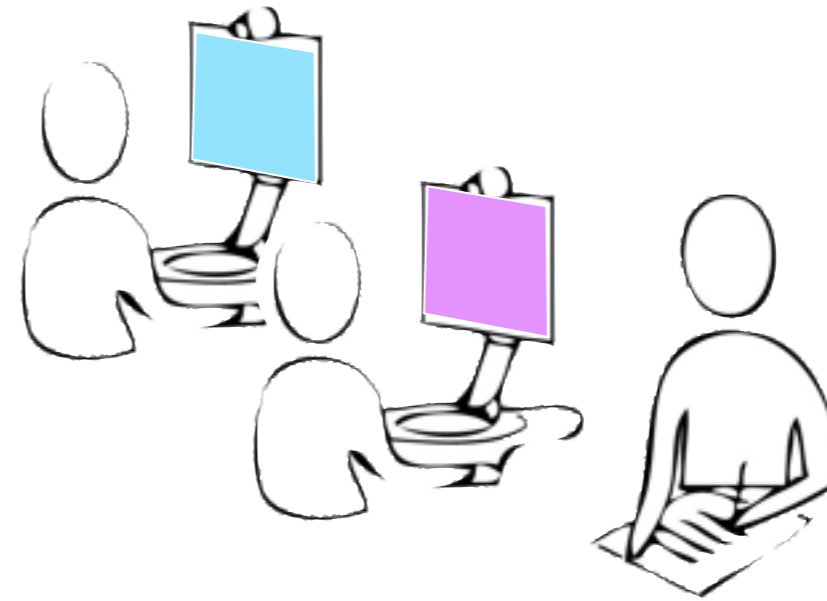
Think-aloud protocol

# POST-HOC COMPARISONS

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Passive observation

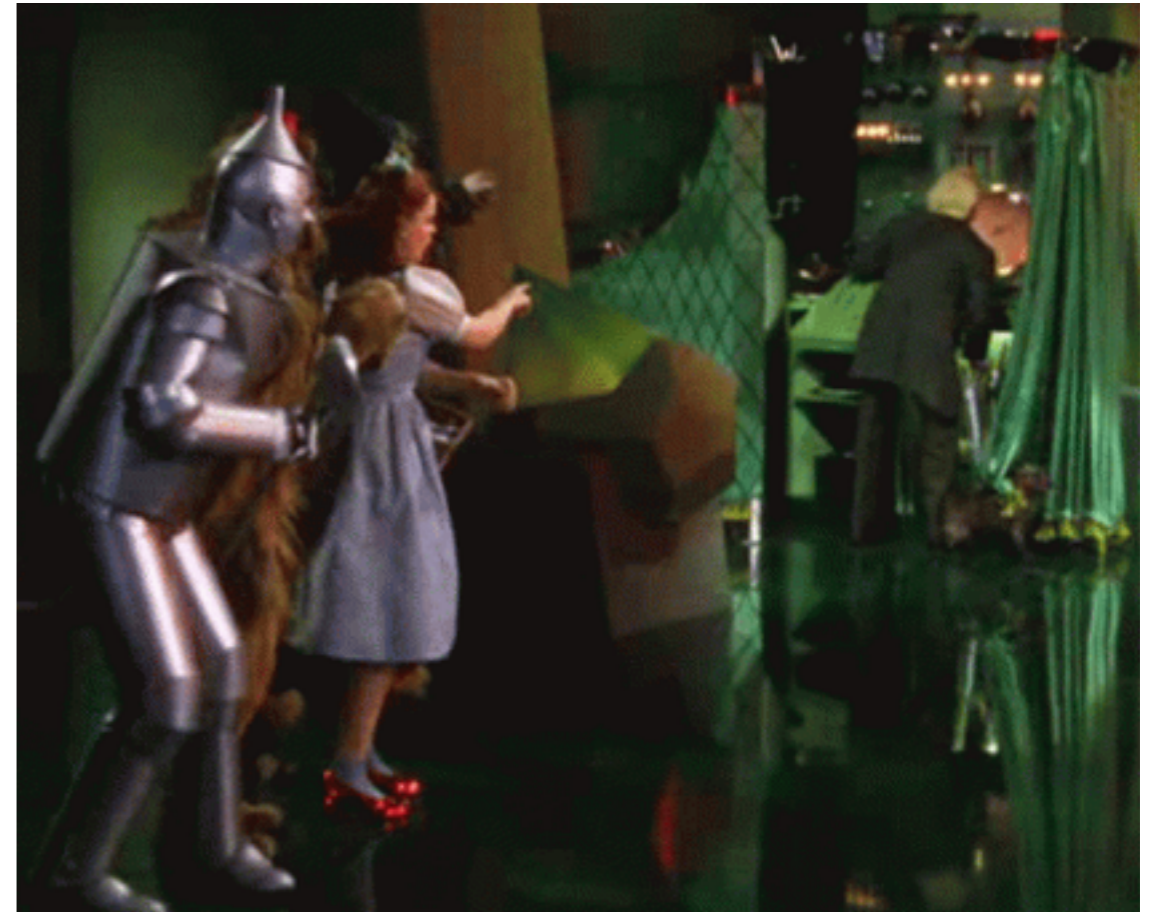
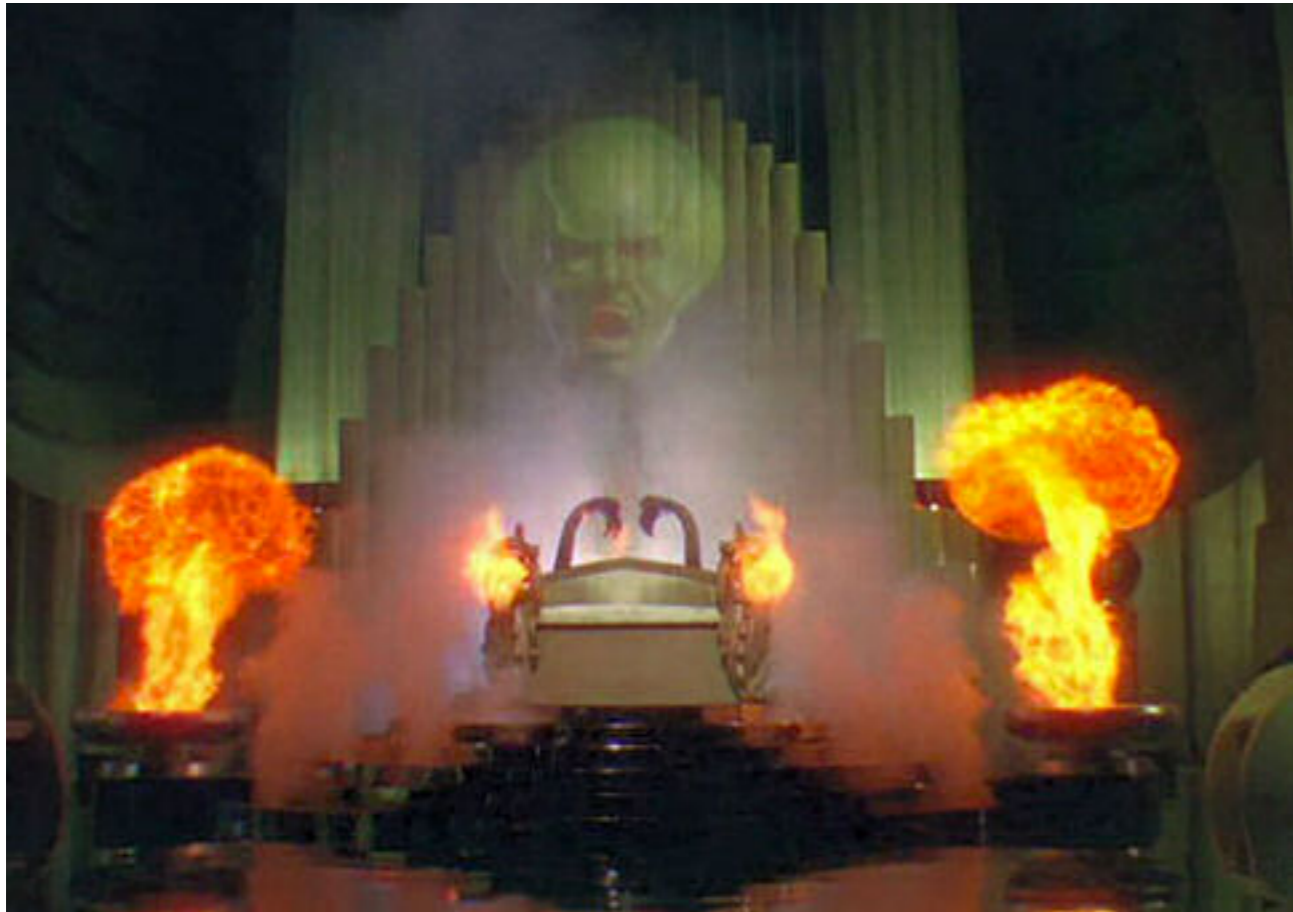


Comparative study



*Post-hoc analysis*

# WIZARD OF OZ





# WIZARD OF OZ

The screenshot displays the Interaction Debugger software interface, which is used for controlling and monitoring a Wizard of Oz experiment. The interface is divided into several panels:

- Time Loader:** Allows setting the date (Mo 13/12/2004) and time (Start Hour: 12, Start Min: 58, End Hour: 12, End Min: 59). It includes a "fix interval" checkbox and a "change time" button.
- Nara\_Spider02:** A video window showing a real-world scene with a robot and a person.
- Nara\_Hearsound:** A volume control window for the robot's audio, with a volume slider from 0 to 100 and a "Mute" button. Current Time: 6.9s.
- Annotation Table:** A table with columns "Time" and "Description". It shows entries for "hug" at 6.8s and "failed" at 6.9s and 12.0s. Below the table is a "Description:" field containing "hug" and an "Annotation:" field containing "The robot hugs pupil but hug behaviour state failed". Buttons for "save", "can...", and "delete" are at the bottom.
- Situation Loader:** Allows selecting a period by setting "Start Date" and "End Date" (both Mo 13/12/2004) and clicking "Load". It also has a "Select annotation" section with a table of annotations.
- Radio Tags (Sp...):** A window showing a list of radio tags for "Spider: 1".
- Sound Level ...:** A window showing a graph of sound level for "Spider: 1" with a "Current Value: 75.7 db".
- Behaviour States:** A table showing the current state of the robot's behaviors.
- Robovie Motion Viewer:** A window showing a 2D schematic of the robot's motion.
- Time Control:** A large slider at the bottom for time control, ranging from 0.0 to 60.0. It includes "Previous", "play", "stop/reset", and "next" buttons. The status bar shows "Total Time: 60.0s", "Current Time: 6.9s", and "Current Unixtime: 1102910286900".

# MODEL HUMAN-HUMAN INTERACTIONS



# Human-Robot Interaction

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