Source: https://www.youtube.com/watch?v=h1E-FlguwGw&t=24s

Lecture 7
“Show me your moves.”
Nonverbal communication

Kim Baraka

Assistant Professor

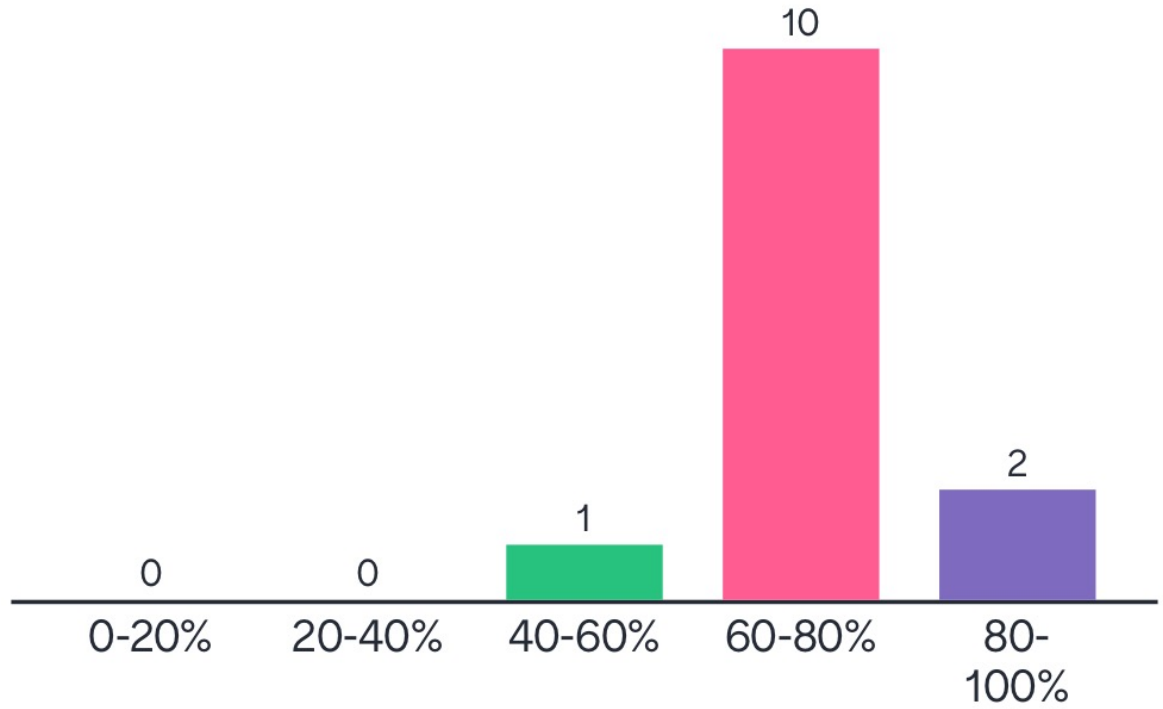
Social AI group

Learning goals

- Get familiar with some *modalities* of human-human non-verbal communication
- Apply and expand on these modalities in the context of HRI
- Design a user study to *evaluate* the effectiveness of non-verbal robot behavior

Go to **www.menti.com** and use the code **4913 0463**

How much of human communication is non-verbal?



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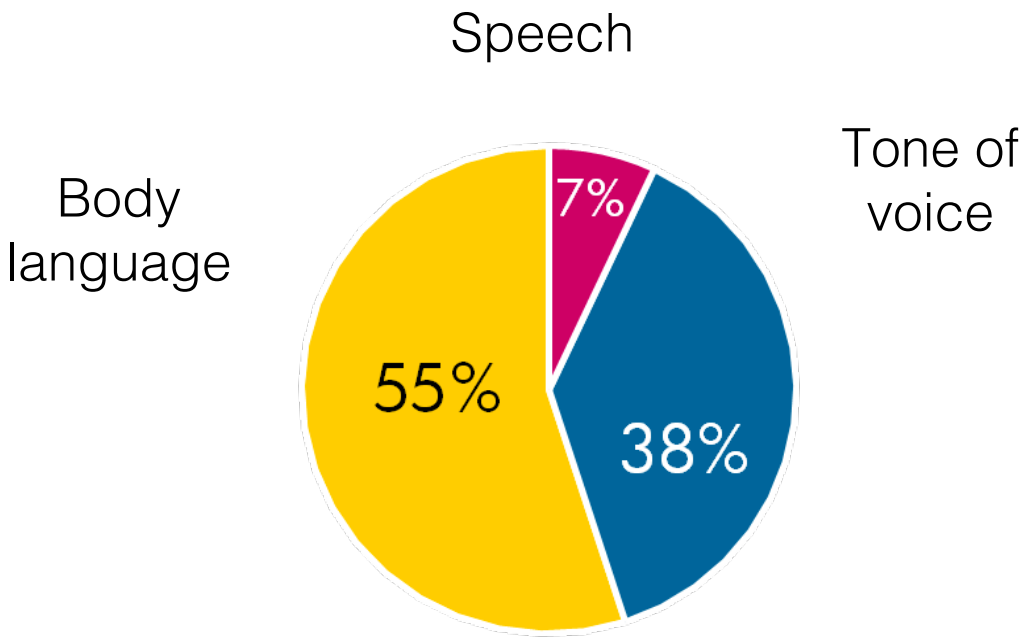

[Mehrabian, 1967]

Go to **www.menti.com** and use the code **4913 0463**

What are some non-verbal modalities in humans?

Voting is closed

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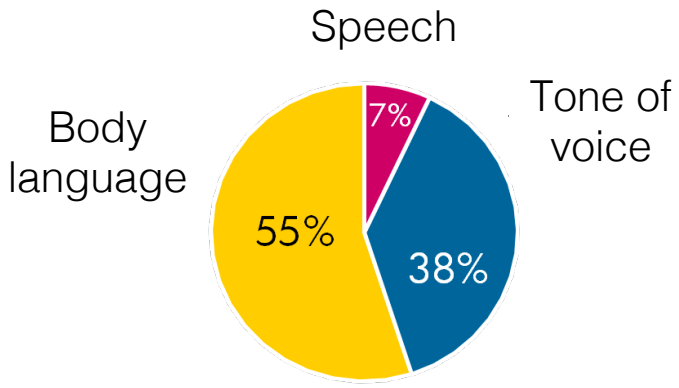
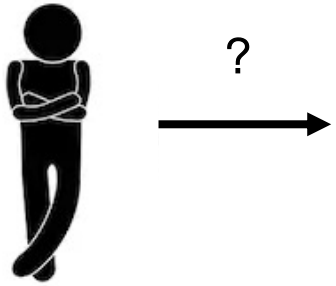
Non-verbal communication (NVC)

- Speech is only a small percentage of human communication



[Mehrabian, 1967]

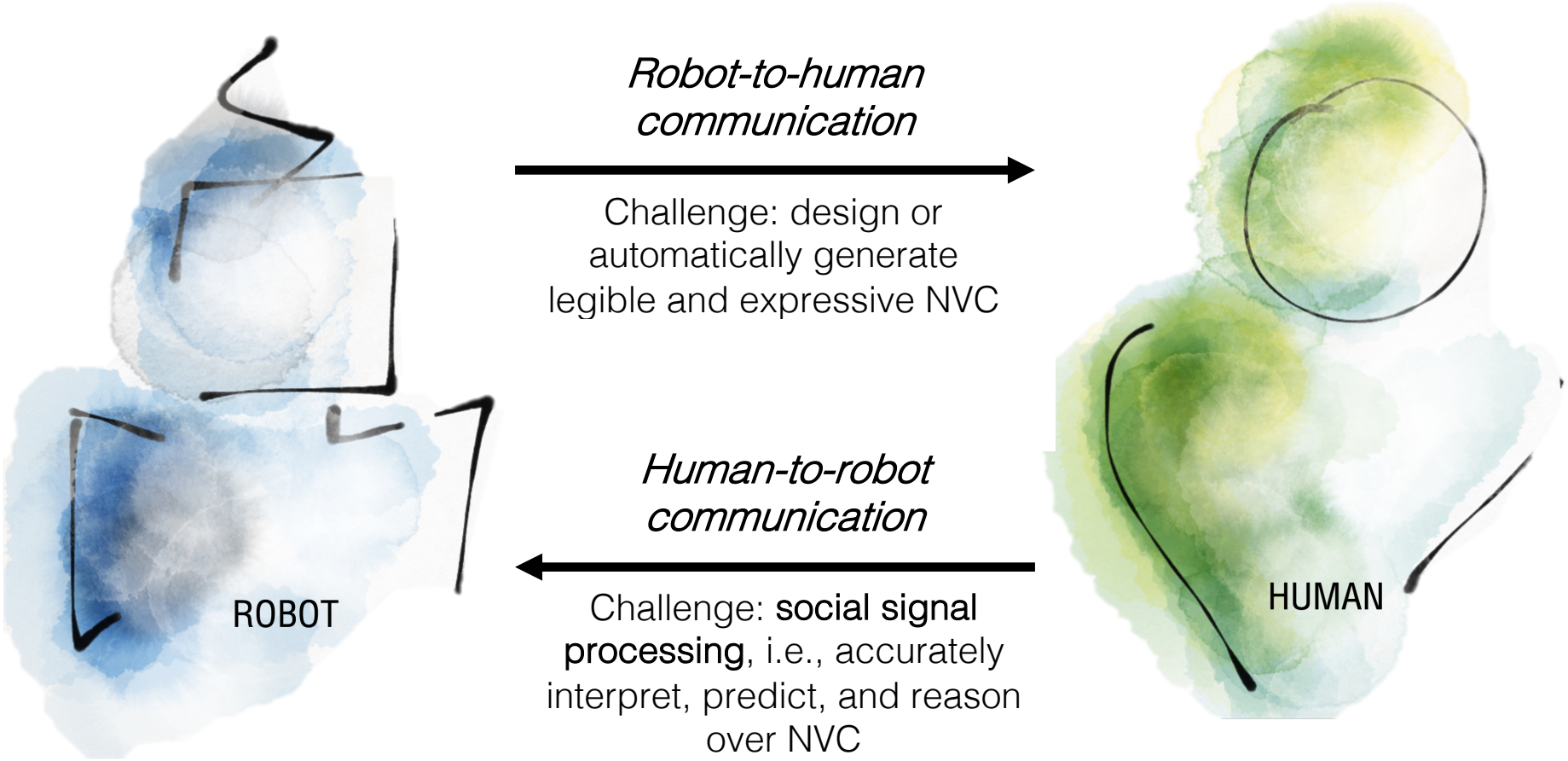
- NVC *modalities* : different ways in which a social agent communicates information without words → social cues
- Challenges for robot NVC
  - Translate principles of human NVC to robots
  - Different embodiment than humans
  - Unique modalities (e.g., lights, sound)




Sphero robot

→ Embodied interaction: “occurring in real time and real space” (Dourish, 2001)

Communication is always a two-way street



Outline

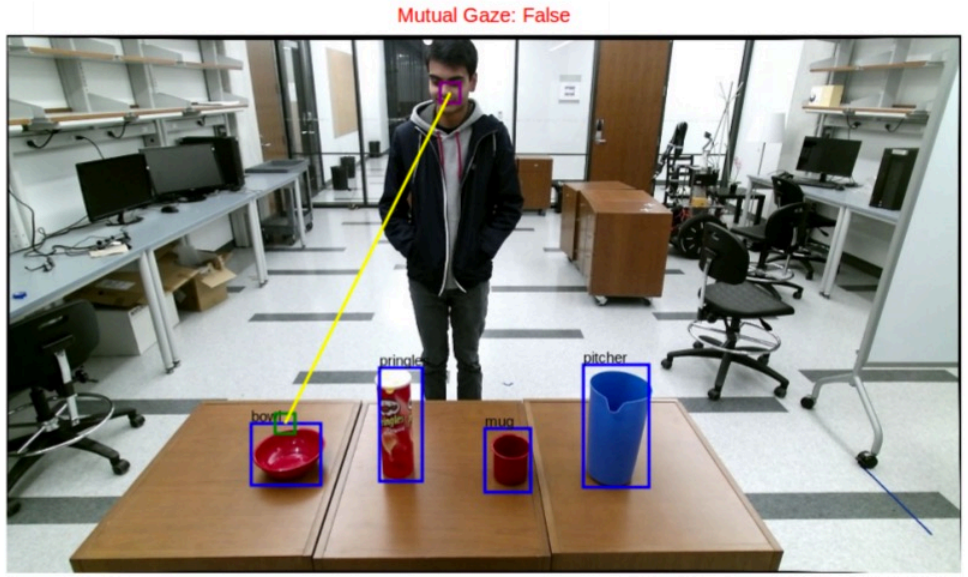
- Gaze
- Gestures
- Expressive motion
- Proxemics
- Haptics
- Prosody
- Robot-specific modalities

Gaze

- Gaze = where and how one looks
- People are uniquely sensitive to gaze – important to get it right on robots
- For non-anthropomorphic robots, gaze doesn't necessarily have to involve realistic-looking eyes
- Three types of gaze
  - Mutual gaze (eye contact)
  - Deictic ("pointing" with your eyes)
  - Joint attention
- Types of eye movement
  - Fixation
  - Saccades
  - Smooth pursuits

JIBO "looking" at a cup

Image Source: talkroute



Saran et al. (2018)

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Gustavo Dudamel (source: YouTube)

Gestures

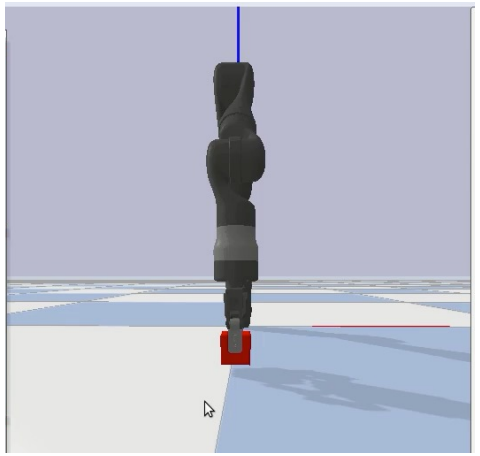
A movement usually, of the body or limbs, that expresses or emphasizes an idea, sentiment, or attitude

- Iconic – represent concrete objects or actions
- Metaphoric – representation abstract concepts
- Deictic – references entities or locations in space
- Beat – follows speech rhythms

Gestures are strongly culturally-dependent

Gesture-controlled robots

Opera Mecatronica, Aerial robotic choir (KTH)

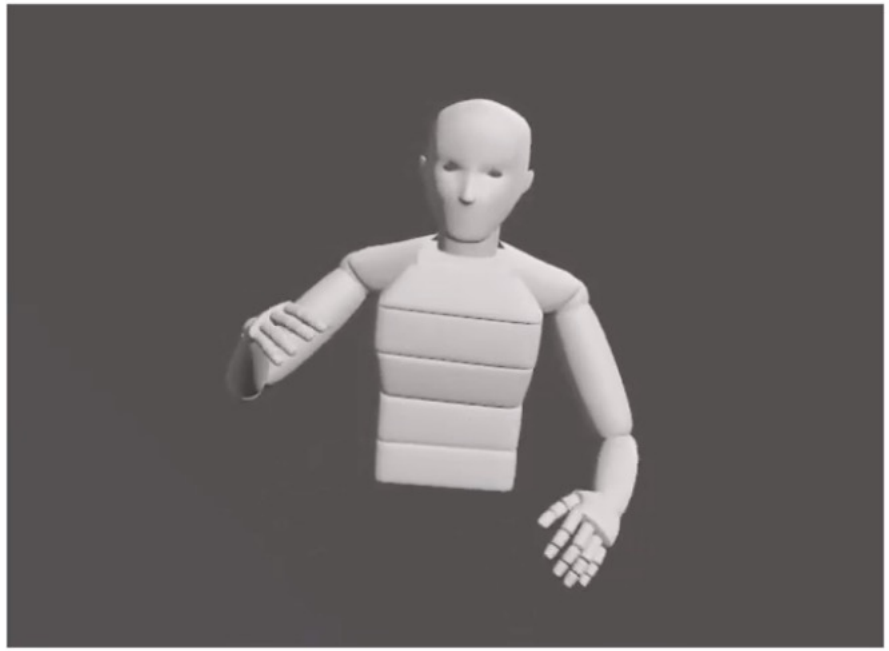


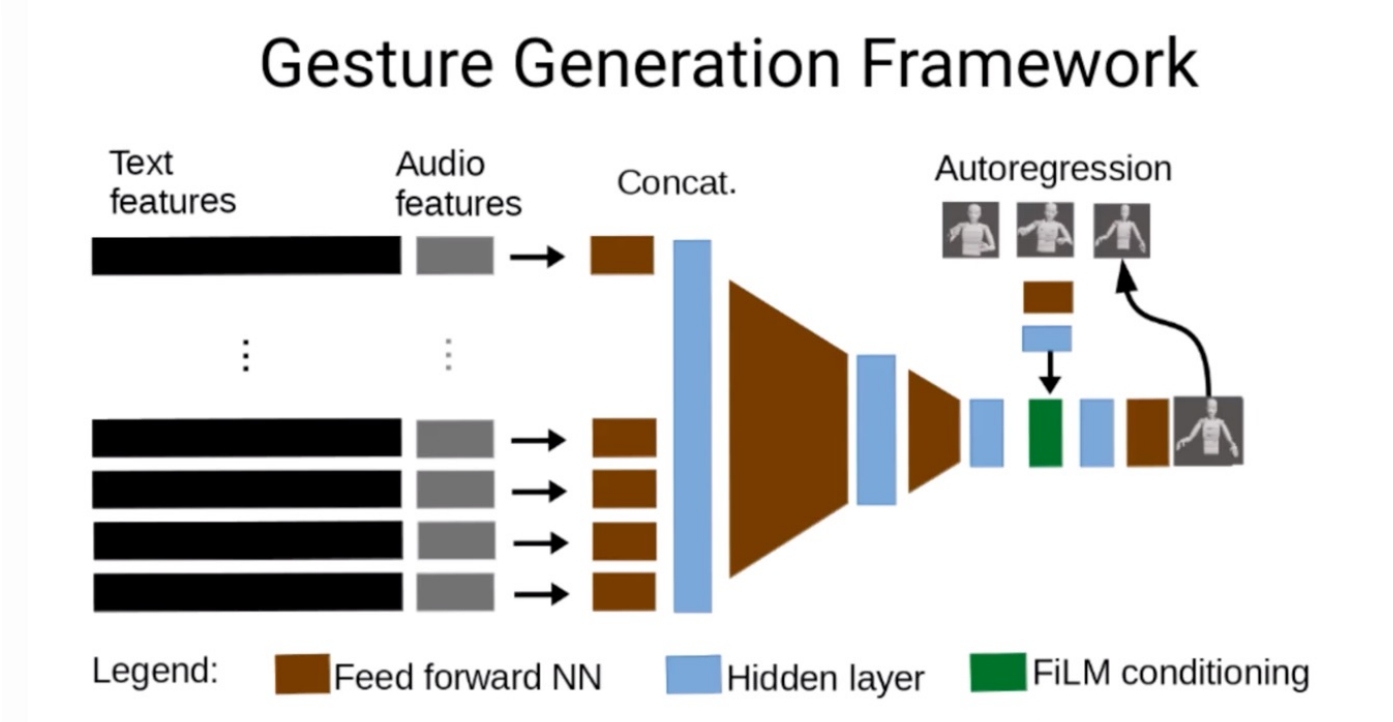
Work in progress in collaboration with UT Austin

Some methods for gesture classification

- RGB vision-based
- Depth vision-based (Leapmotion)
- Motion-capture (wearable sensors, or marker-enabled)
- Glove-enabled (Pison https://www.youtube.com/watch?v=bsF7be6wBrg)

Automatic generation of speech-accompanying gestures





Gesticulator: A framework for semantically-aware speech-driven gesture generation (Kucherenko et al. 2020)

Activity

For people in the classroom:

Student 1: explain to student 2 to how to get from here to the lab.

Student 2: Observe NVC, especially types of gaze and gesture

For people at home:

If you have company, ask them to tell you how to get to the nearest supermarket

Cheat sheet

Gaze

- Mutual gaze
- Deictic
- Joint attention

Gestures

- Iconic
- Metaphoric
- Deictic
- Beat

What kind of NVC did you use?

Outline

- Gaze
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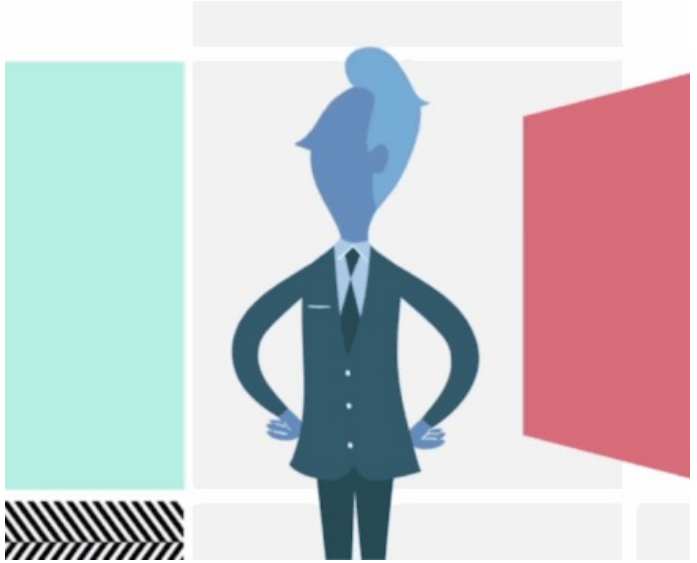
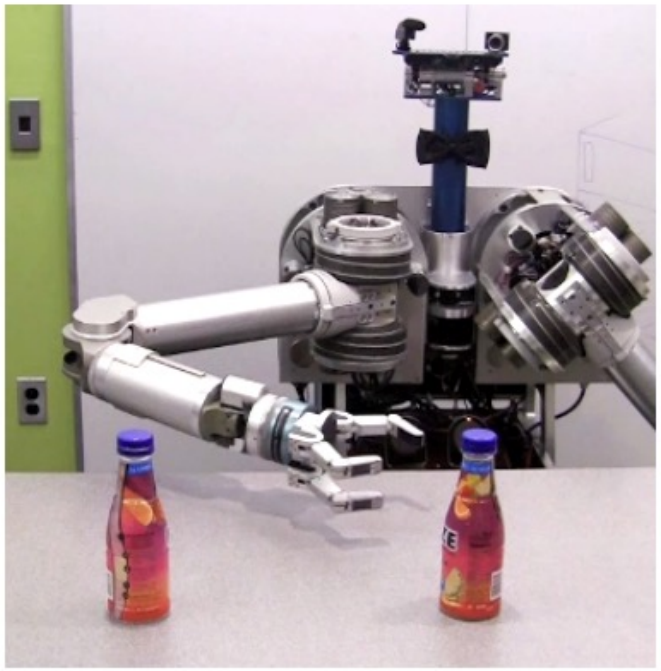
Expressive motion

- Motion with a primarily functional purpose, modulated for a communicative purpose
- Expresses a hidden component of the robot's program (e.g., state, goal, intent, performance, affect, etc.)
- Can interfere with robot operation or performance

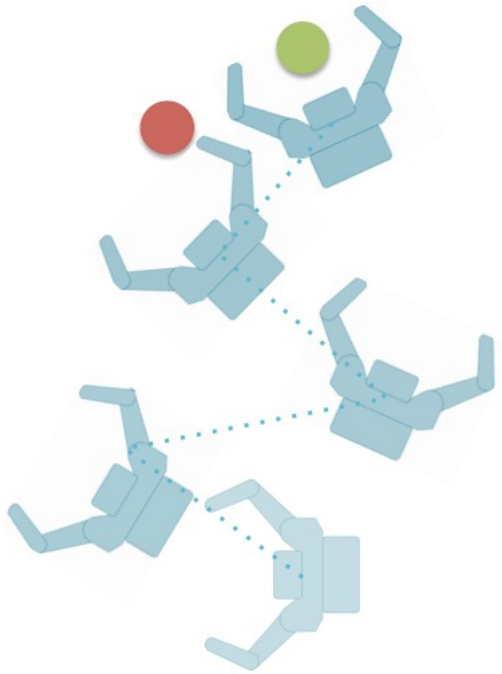


Scandis (IdeaRocket) (Source: Vimeo)

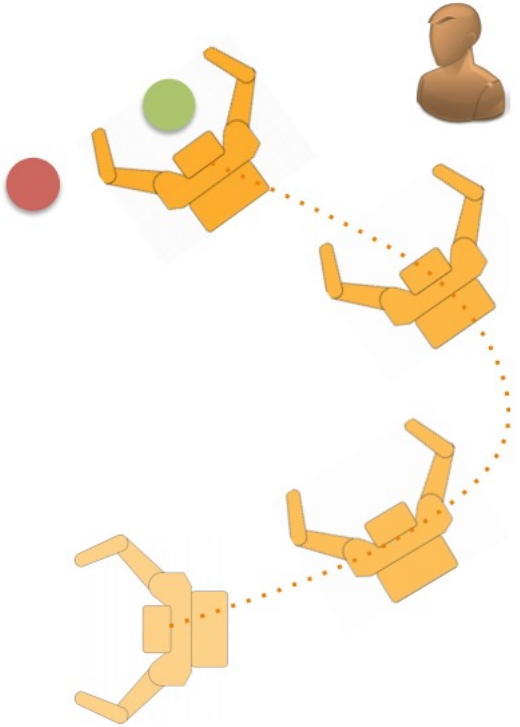
Expressive motion (manipulator) [Dragan, 2015]



HERB manipulator

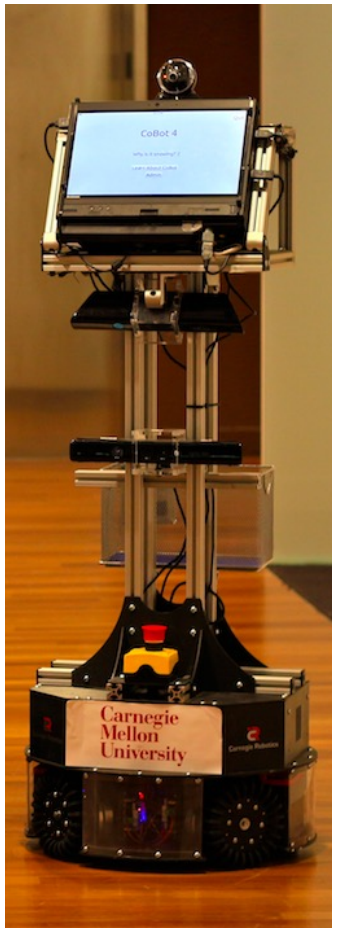


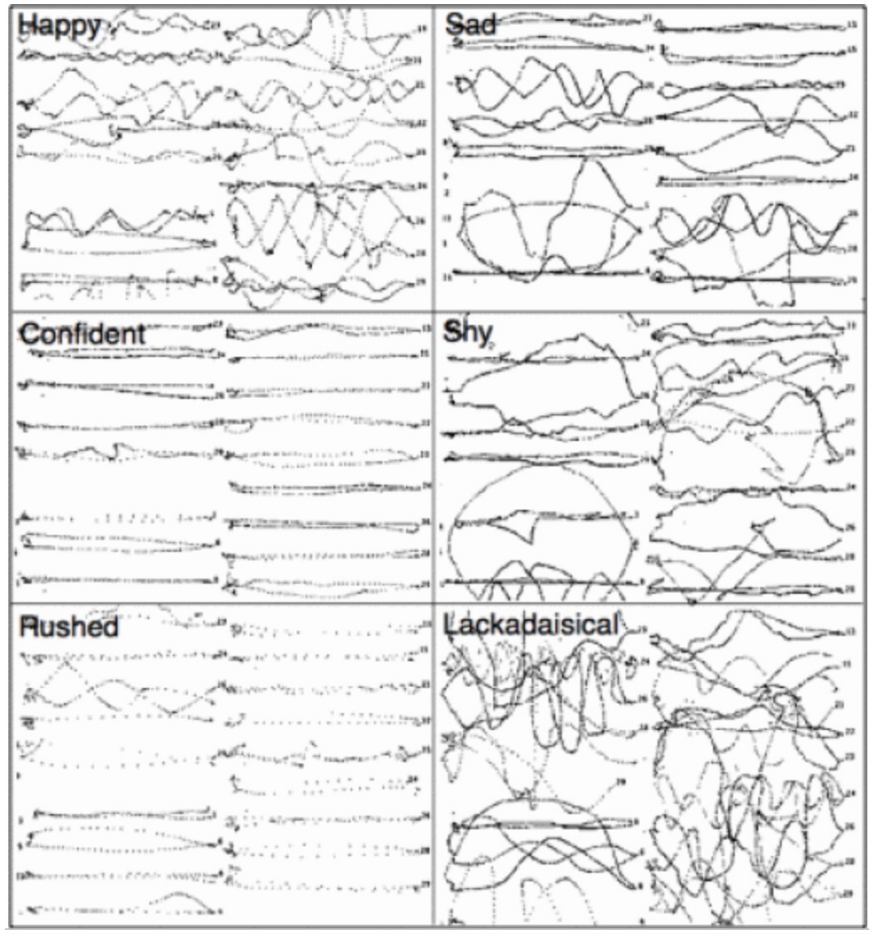
Functional motion



Legible motion

Expressive motion (mobile robot) [Knight et al., 2014]





- Motions in x, y, and theta inspired by the Laban effort framework (dance)
- Design of trajectories involved the participation of actors

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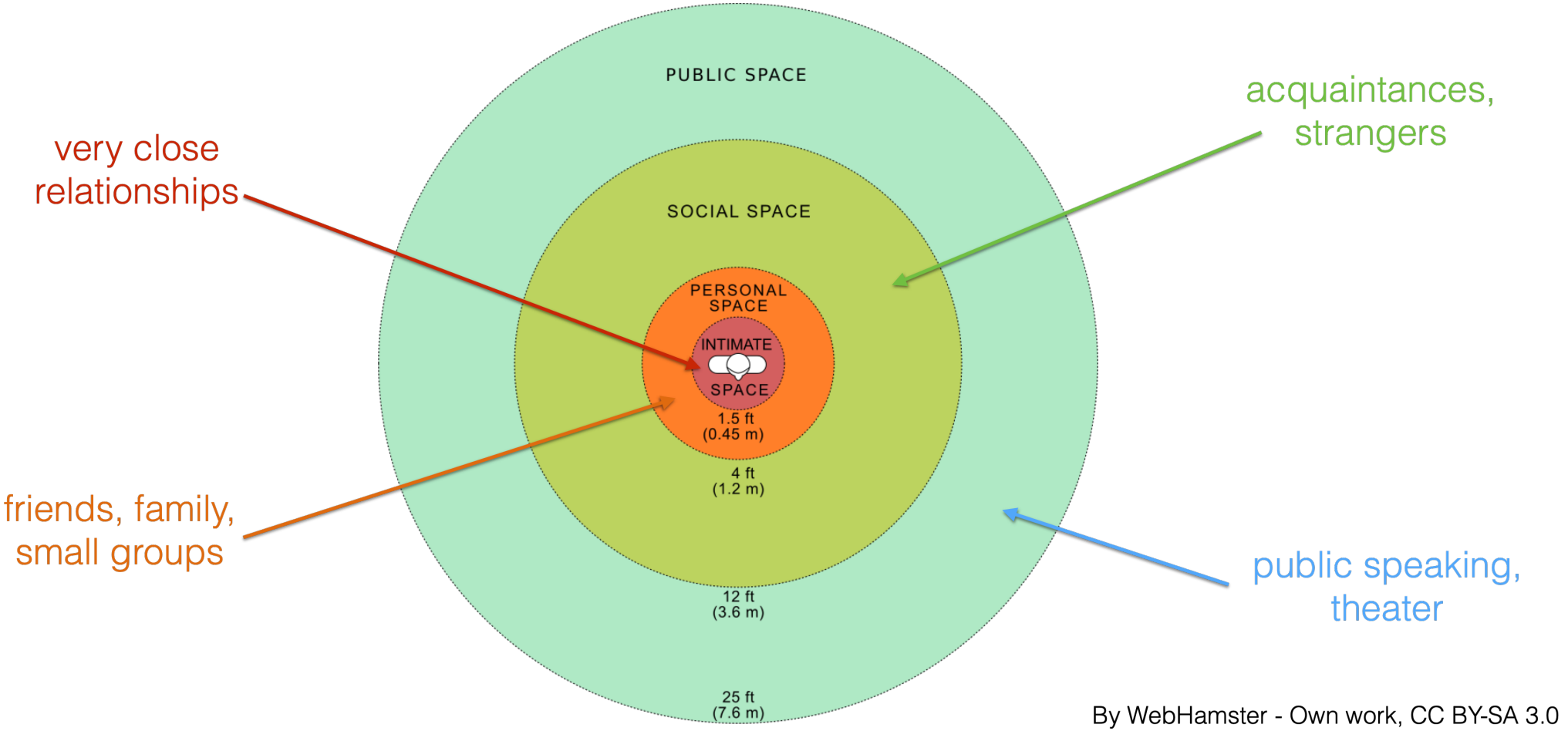
Proxemics

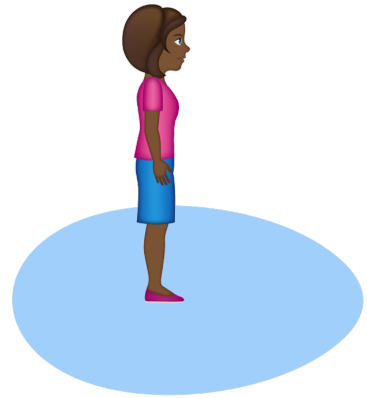
- "the study of spatial distances individuals maintain in various social and interpersonal situations." — Rios-Martinez et al. (2015)
- First introduced by Edward T. Hall in 1966
- A key part of interpersonal communication
- Strongly influenced by
  - personal factors (age, gender)
  - environmental factors (task, noise, context)
  - societal factors (culture)

Hall's interpersonal distances



Personal space

- Personal space is egg-shaped, longer in front than in the rear (Hayduk et al., 1981)



- When physical proximity is out of sync with social connection, people diffuse the discomfort by avoiding eye contact and conversation (Shaver, *Principles of Social Psychology*, 2015)

Quora user Ciril J Thundiyil

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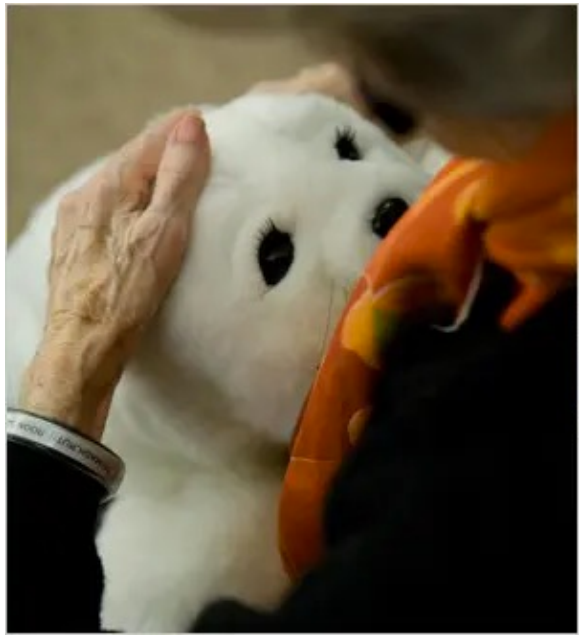
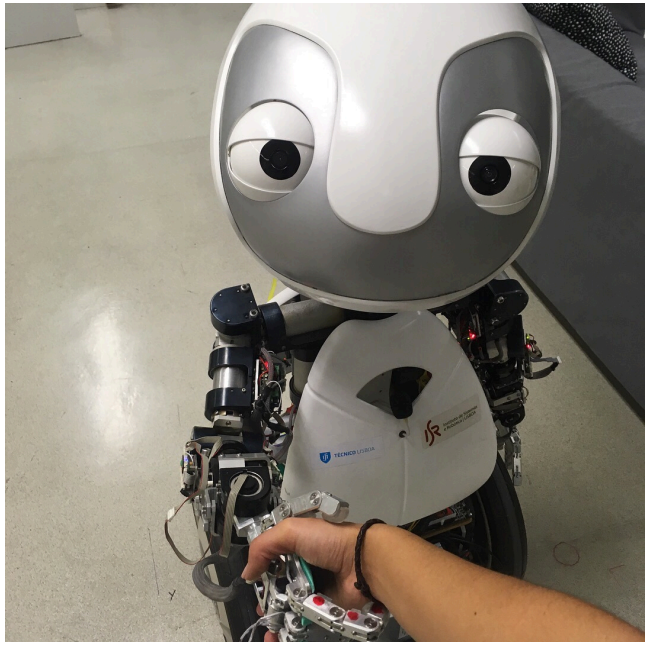
Haptics

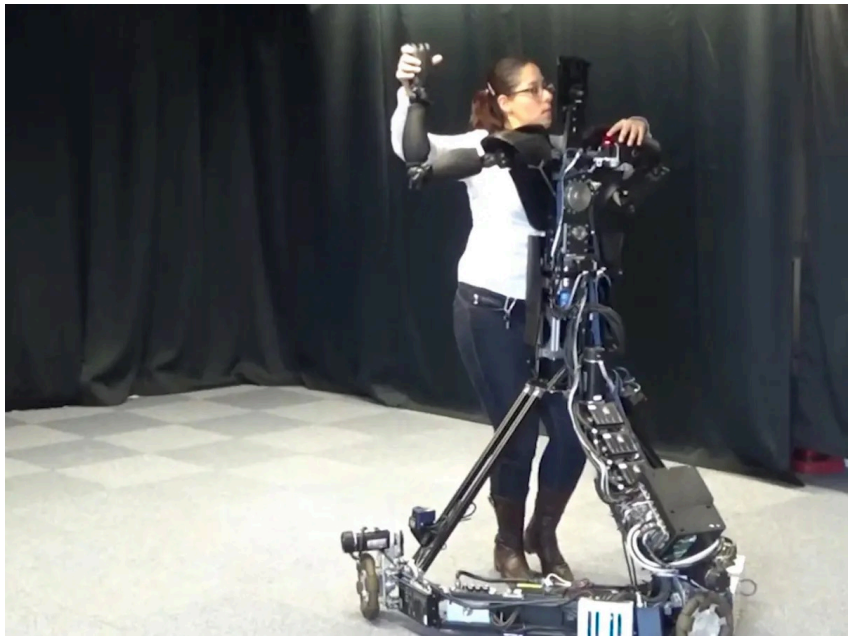
Touch, texture, pressure, force, etc.



PARO being touched.
Credits: New York Times



Avelino et al. (2018)



Granados et al (2017)

Contact improvisation with a Baxter robot: communication through weight sharing, negotiation of pressure, and exploring leader-follower dynamics

(in collaboration with Isabel Valverde, Ana Moura, and Nuno Leite)

https://www.youtube.com/watch?v=PNzeT8ZsyfM&ab_channel=NunoLeit

Collaborative painting through shared control of a paintbrush

(in collaboration with Robert Zacharias, Yeliz Karadayi, and Su Baykal)

https://www.youtube.com/watch?v=A96bW_4CtQc&ab_channel=bobbyzacharias

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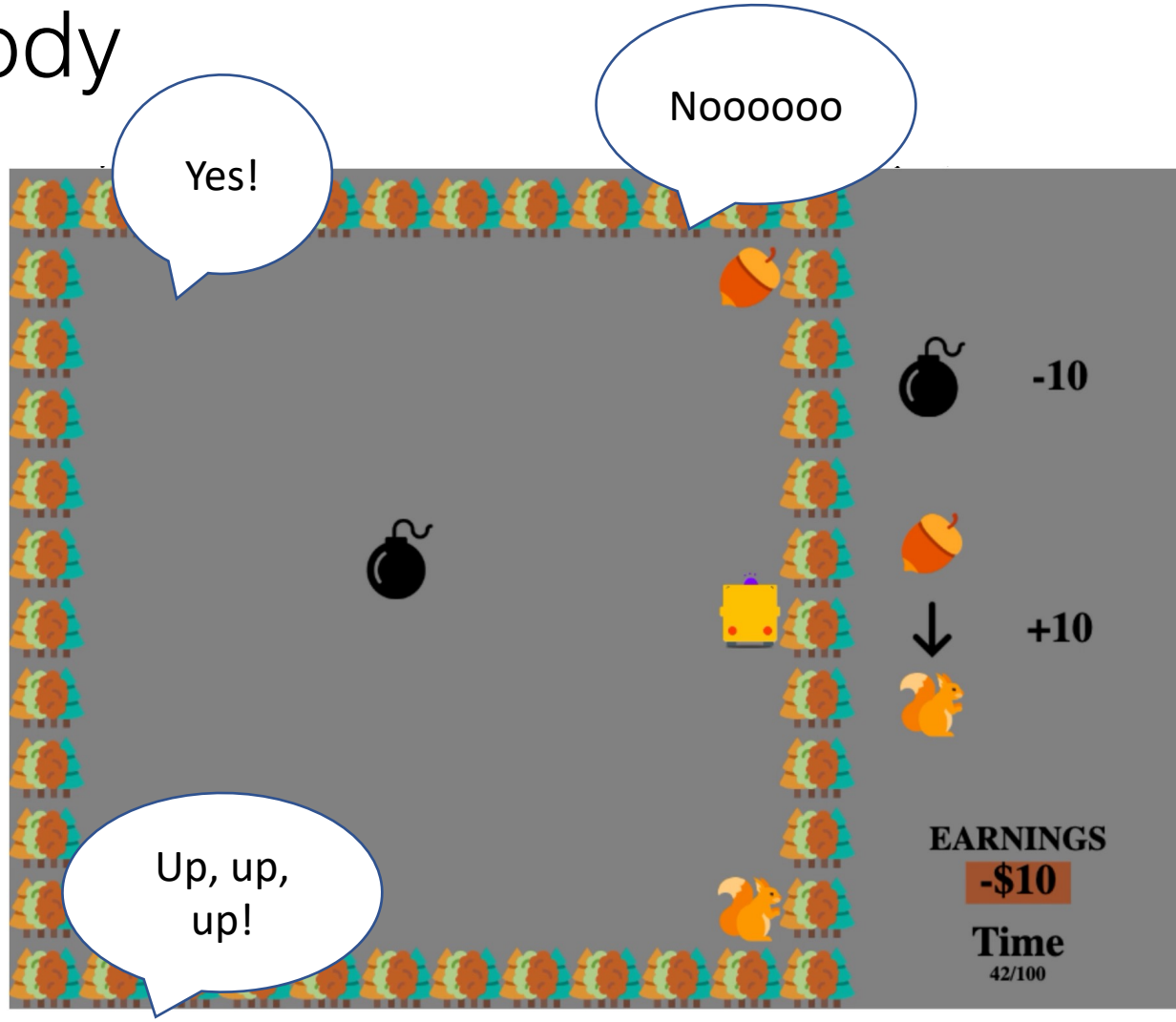
Prosody

"The rhythm, stress, and intonation of speech" (APA)
Not **what** is being said, but **how** it is being said

- Appropriately modulating prosody on a robot is difficult
- Extracting prosodic cues from human voice can be used to extract more task-relevant or internal state information



Prosody sensitive learning: Work in progress in collaboration with UT Austin

Outline

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Go to **www.menti.com** and use the code **5711 7498**

Robot-specific NVC modalities?

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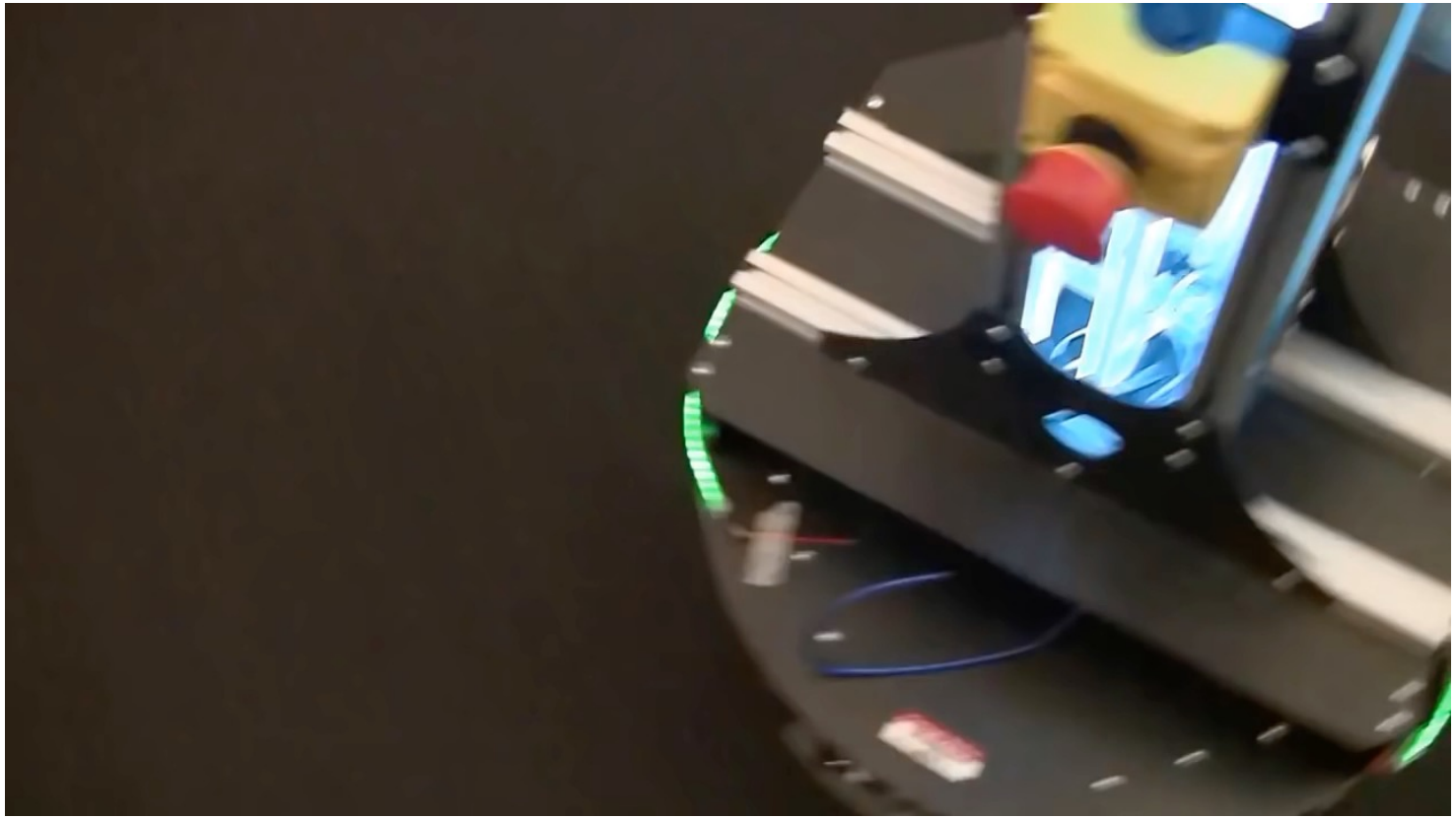
Expressive lights [Baraka et al., 2018]



https://www.youtube.com/watch?v=pNPINDh2fYo&ab_channel=KimBaraka

- Increases state and action *transparency* (What is the robot "thinking"? Why did the robot do that?)
- Contributes to predictability and trust

How to evaluate that a given non-verbal robot behavior communicates effectively?

Evaluation methods

- Identify the intended *goal* of the communication (e.g., reveal internal state, communicate goal or intent, express affect, etc.)

- Select appropriate *measures* for its success (people guess right, people adapt their behavior, people trust more, etc.)

- Show the robot performing the same task, under two *conditions*:

  (C1): With NVC
  (C2): Without NVC

- *Compare* the measures under both conditions using statistical tests

Example: expressive lights

[Baraka et al., 2016]

Goal of communication:

Reveal internal state

Measure:

Accuracy on answering questions about robot state (multiple choice), e.g.:

- “What is the robot doing?”
- “Why did the robot…?”

Example: expressive lights

[Baraka et al., 2016]

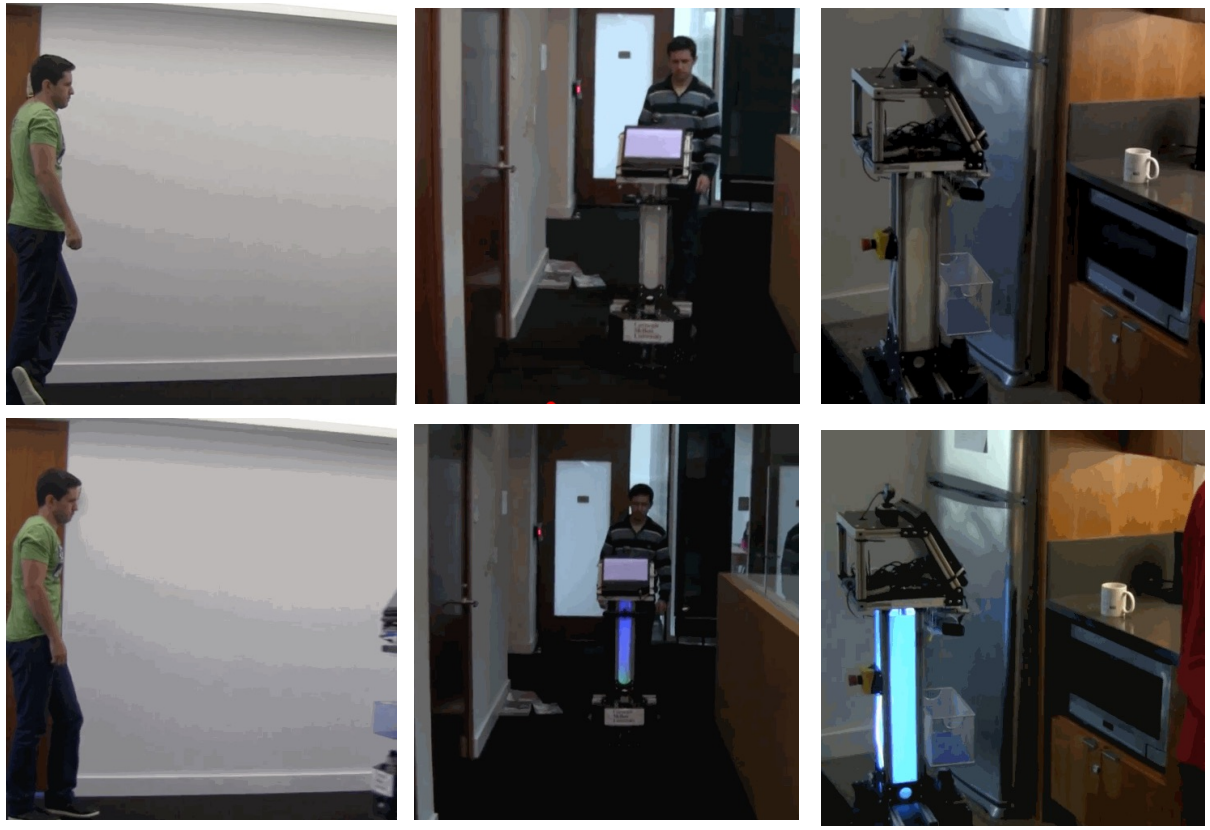
Goal of communication:

Reveal internal state

Measure:

Accuracy on answering questions about robot state (multiple choice), e.g.:

- “What is the robot doing?”
- “Why did the robot…?”



C1:
Lights OFF

C2:
Lights ON

Example: expressive lights

[Baraka et al., 2016]

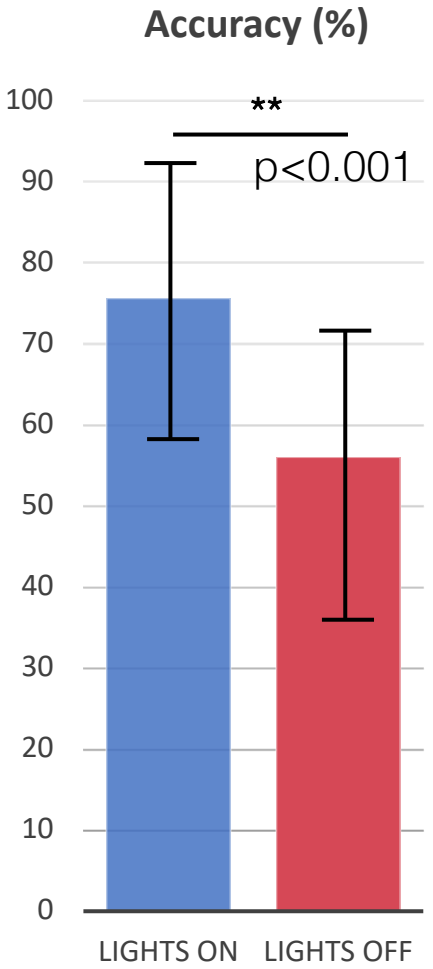
Goal of communication:

Reveal internal state

Measure:

Accuracy on answering questions about robot state (multiple choice), e.g.:

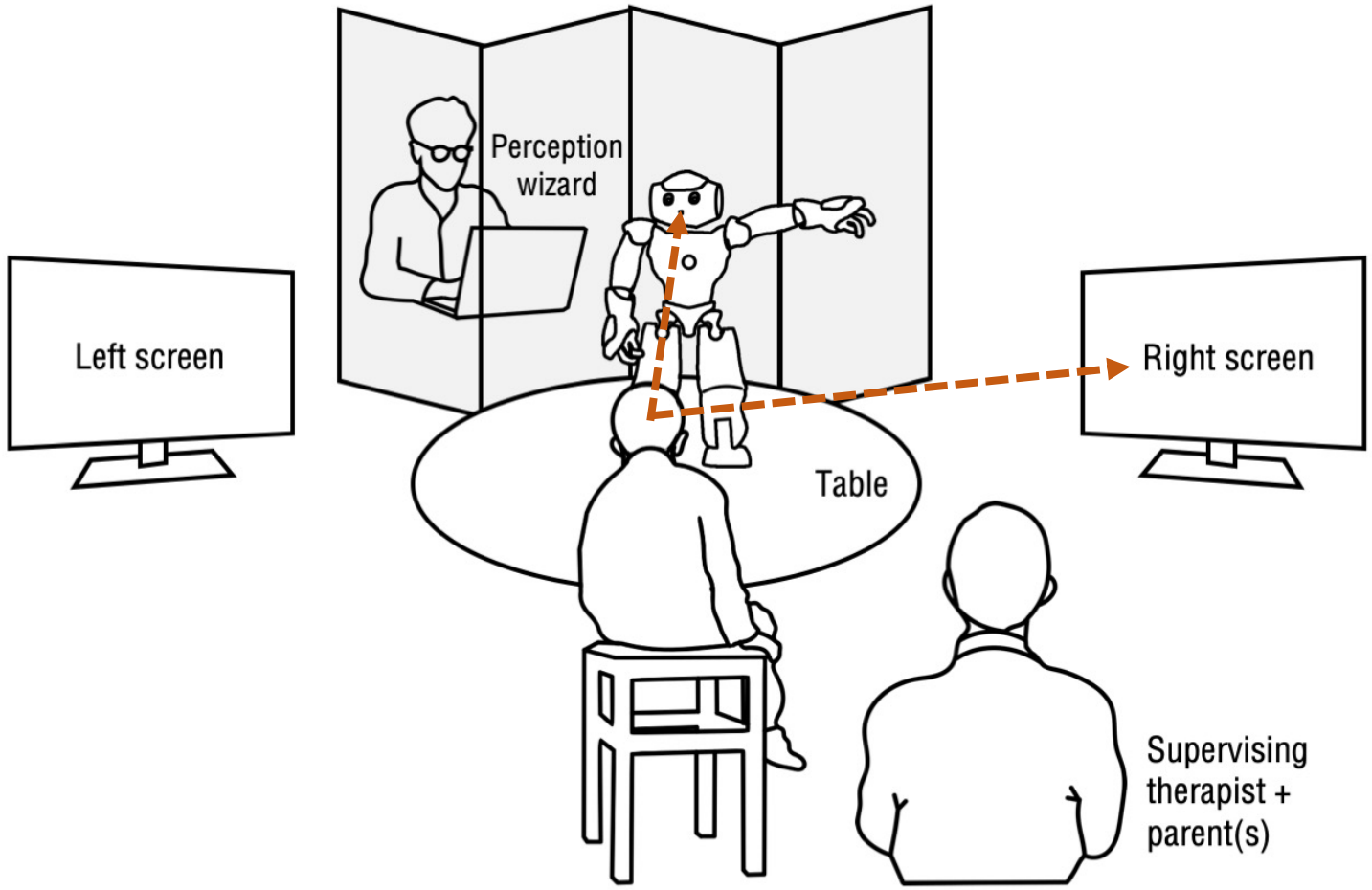
- "What is the robot doing?"
- "Why did the robot…?"



Multi-modal NVC

- Multi-modal NVC usually means richer NVC
- Challenges of interpreting multi-modal human NVC signals?
- Challenges of producing robot NVC?
- What are some cases of undesirable multi-modal NVC?
  - Therapeutic contexts where you want children to learn more subtle NVC (example on next slides)

Intervention for children with autism (joint attention)



“An Optimization Approach for Structured Agent-Based Provider/Receiver Tasks” (Baraka et al., 2019)

Action hierarchies

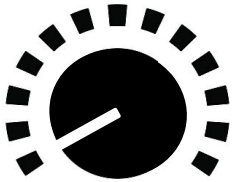
Increasingly assistive / more multi-modal

Level	JATT	NAME
1	Speech+gaze	Brief speech
2	Speech+gaze+pointing	Speech
3	Speech+gaze+pointing+video	Speech+lights
4	Speech+gaze+pointing+video+sound	Speech+lights+motion

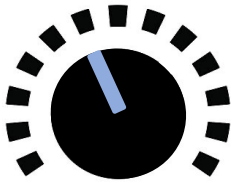
Higher level in the hierarchy works better for higher autism severity but doesn't challenge children with low severity enough – how to select the optimal level?

"An Optimization Approach for Structured Agent-Based Provider/Receiver Tasks" (Baraka et al., 2019)

Just-right challenge: analogy with bike riding

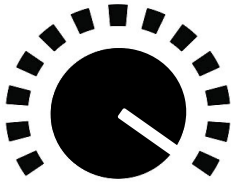


Under-assist → task failure



Just-right → learning

Similar to the zone of proximal development concept from Mark Neerincx's lecture



Over-assist → no learning

Photo credit: UC Berkeley

Summary

- NVC is essential for *embodied interaction* with humans
  Contributes to fluidity, transparency, trust,…

- NVC modalities include (but are not limited to): gaze (mutual gaze, deictic, joint attention, …), gestures (iconic, metaphoric, beat, …), expressive motion, proxemics (interpersonal distances and personal space), haptics (physical HRI), and prosody

- Robot-specific modalities include lights, sound, and robot-specific motion

- NVC is still a vast open area of research in HRI