Artificial Intelligence Course of the Master Degree on Cognitive Science
09/11/2021 - Invited Lecture on:

Social Robots

Human-Robot Interaction

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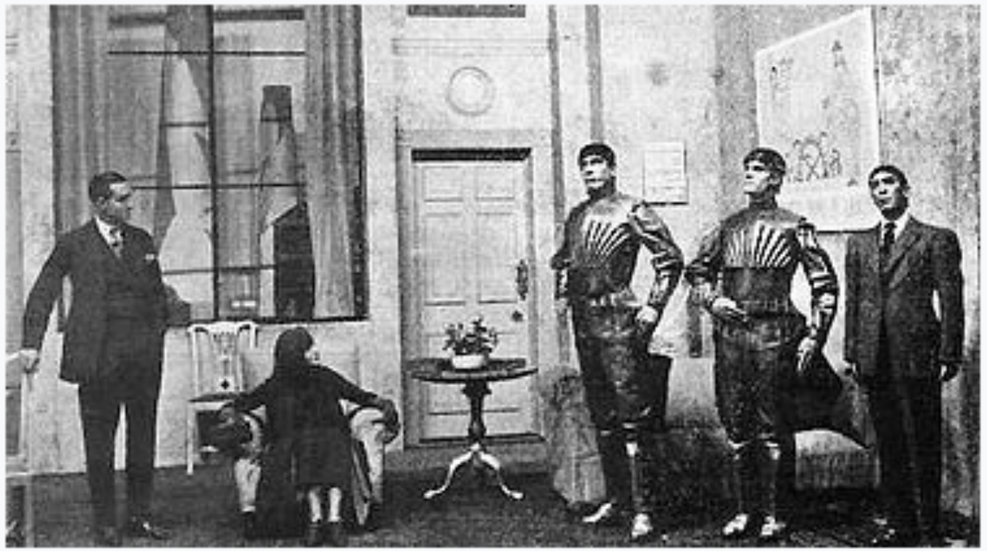
Outline

- Robots & Social Robots
- Human-Robot Interaction
    - Application Areas
    - Relational Roles
    - Proximity
    - Temporal Profile
    - Appearance
    - Autonomy & Intelligence
    - Social Capabilities
- Computational Models for Human-Robot Teams in Multiparty Settings

The word “robot”

- Slavic word “robota” means “forced labor”
- Czech writer Karel Čapek first used the word “robot” as “artificial automata” in his play in 1921

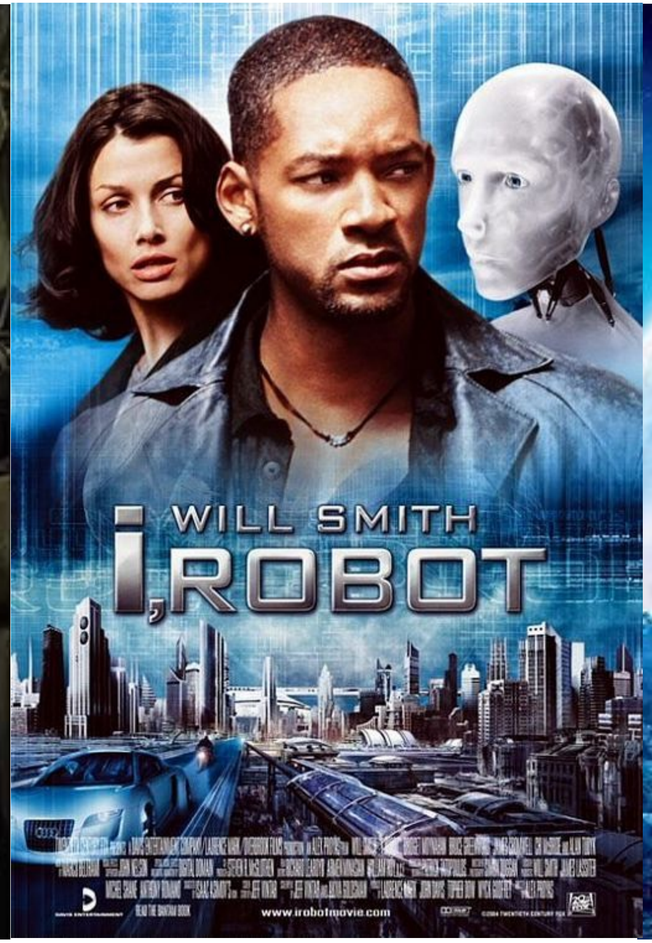
R.U.R.



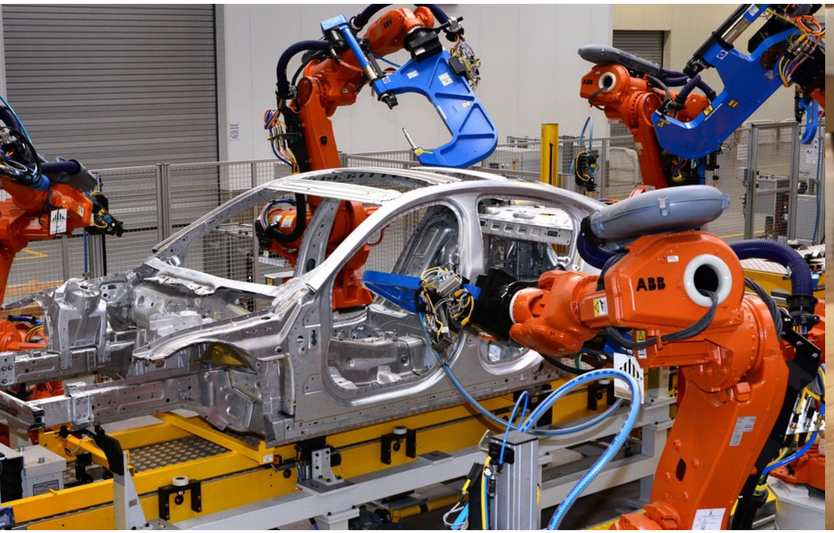
A scene from the play, showing three robots

Written by	Karel Čapek
Date premiered	2 January 1921
Original language	Czech
Genre	Science fiction

Science Fiction Movies



Which robots can we find today?



What is a Robot?

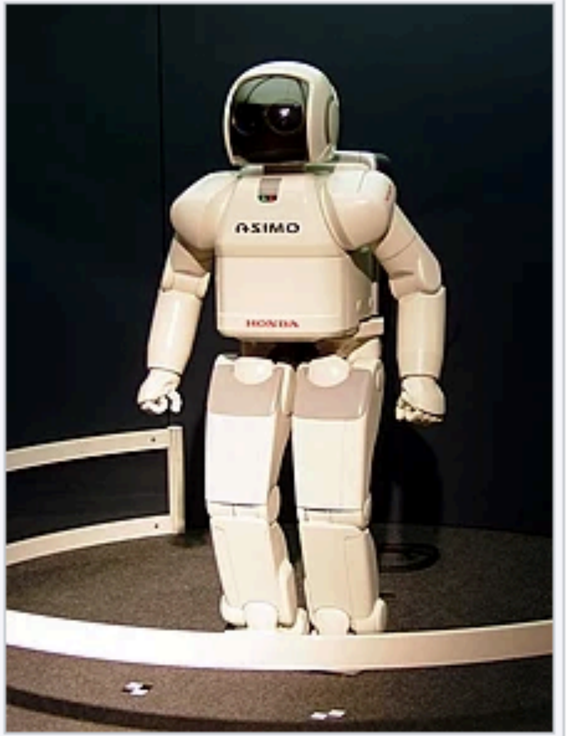
- A machine that exists or is embodied in the real world
- Execute actions in that world
    - Does it imply movement?

Robot

From Wikipedia, the free encyclopedia

This article is about mechanical robots. For software agents, see Bot. For other uses of the term, see Robot (disambiguation).

A **robot** is a machine —especially one programmable by a computer —capable of carrying out a complex series of actions automatically.[2] A robot can be guided by an external control device, or the control may be embedded within. Robots may be constructed to evoke human form, but most robots are task-performing machines, designed with an emphasis on stark functionality, rather than expressive aesthetics.



ASIMO (2000) at the Expo 2005

What is a Social Robot?

Social robot

From Wikipedia, the free encyclopedia

A **social robot** is an autonomous robot that interacts and communicates with humans or other autonomous physical agents by following social behaviors and rules attached to its role.

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Social robots are embodied agents that are part of a heterogeneous group: a society of robots or humans. They are able to recognize each other and engage in social interactions, they possess histories (perceive and interpret the world in terms of their own experience), and they explicitly communicate with and learn from each other.

- Dautenhahn & Billard, 1999

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Social robots constitute:

A physical entity embodied in a complex, dynamic, and social environment sufficiently empowered to behave in a manner conducive to its own goals and those of its community

- Duffy et al., 1999

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Classes of Social Behavior

Breazeal, 2003

- Socially evocative
- Social interface
- Socially receptive
- Sociable

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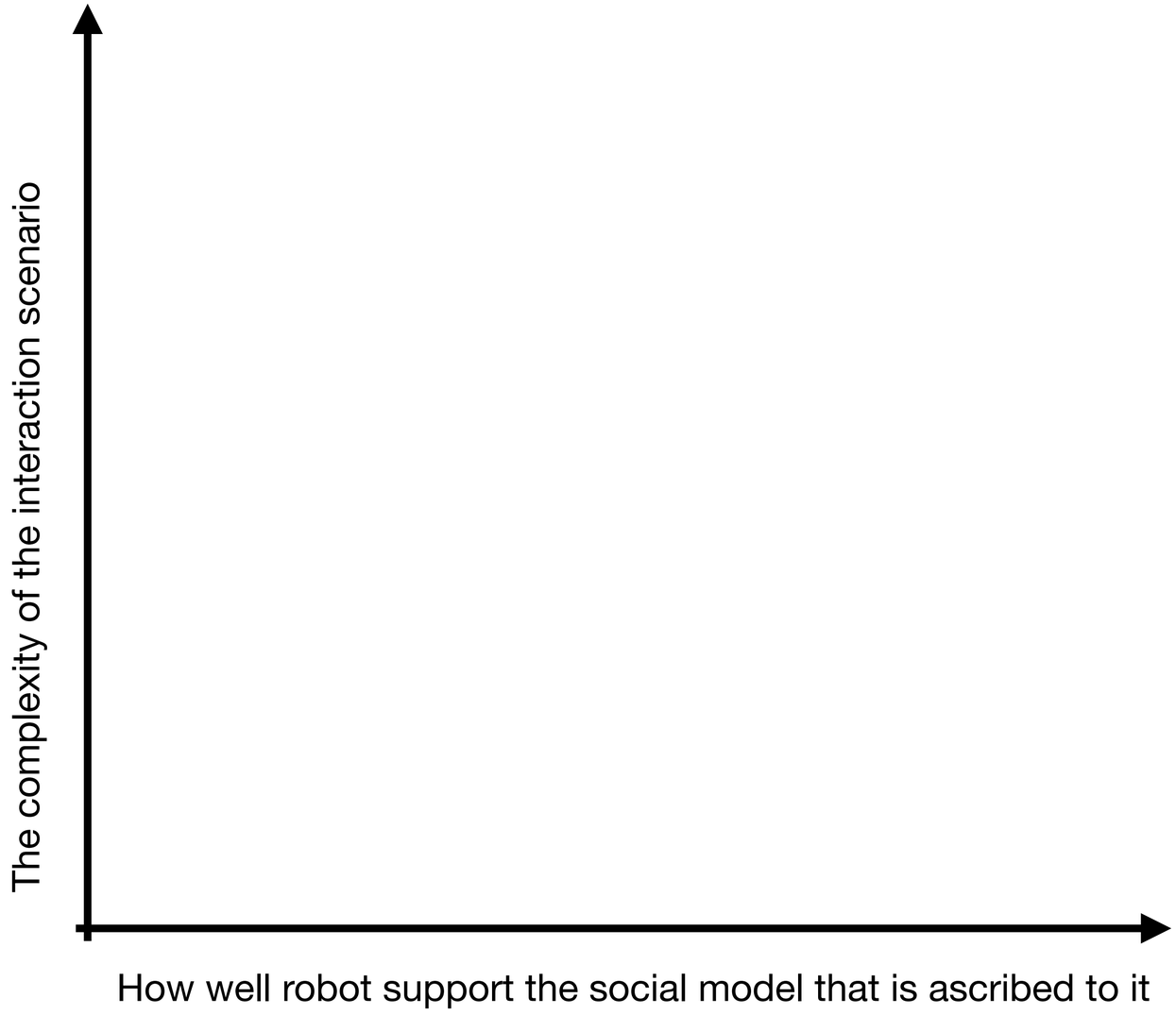
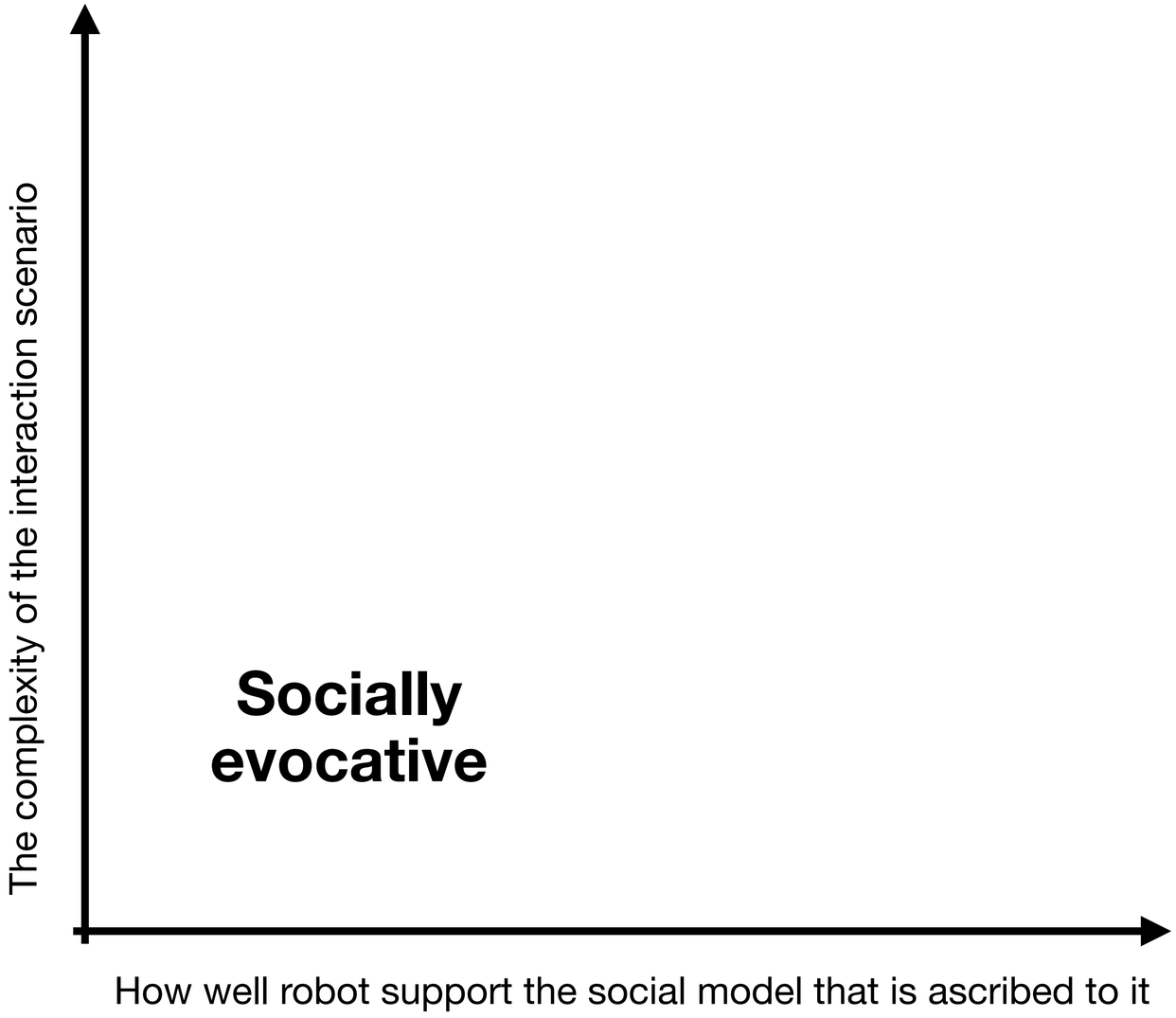


Classes of Social Behavior

Breazeal, 2003

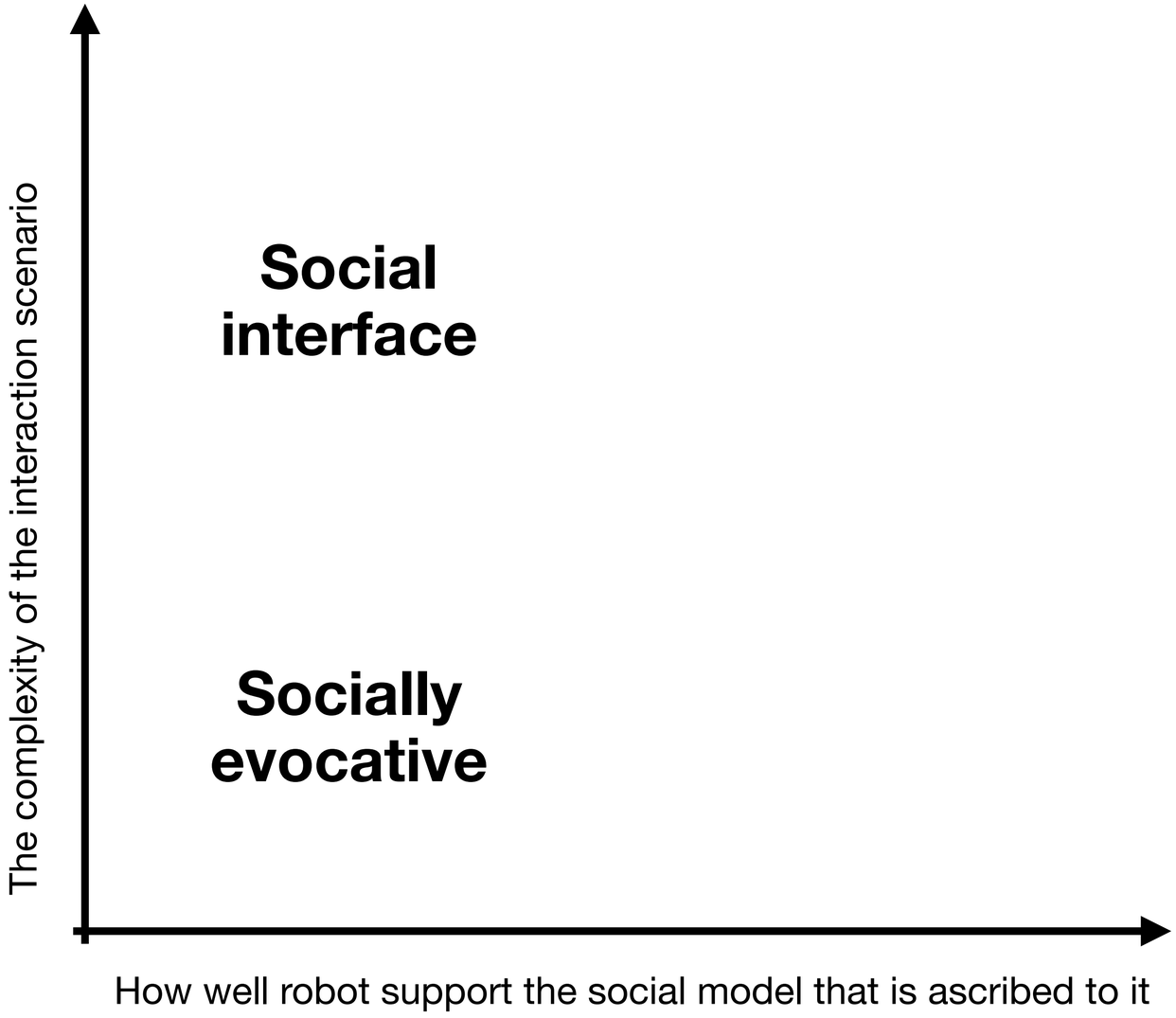
- **Socially evocative.** Robots that rely on the human tendency to anthropomorphize and capitalize on feelings evoked when humans nurture, care, or involved with their “creation”.



Classes of Social Behavior

Breazeal, 2003

- **Social interface.** Robots that provide a “natural” interface by employing human-like social cues and communication modalities. Social behavior is only modeled at the interface, which usually results in shallow models of social cognition.



Classes of Social Behavior

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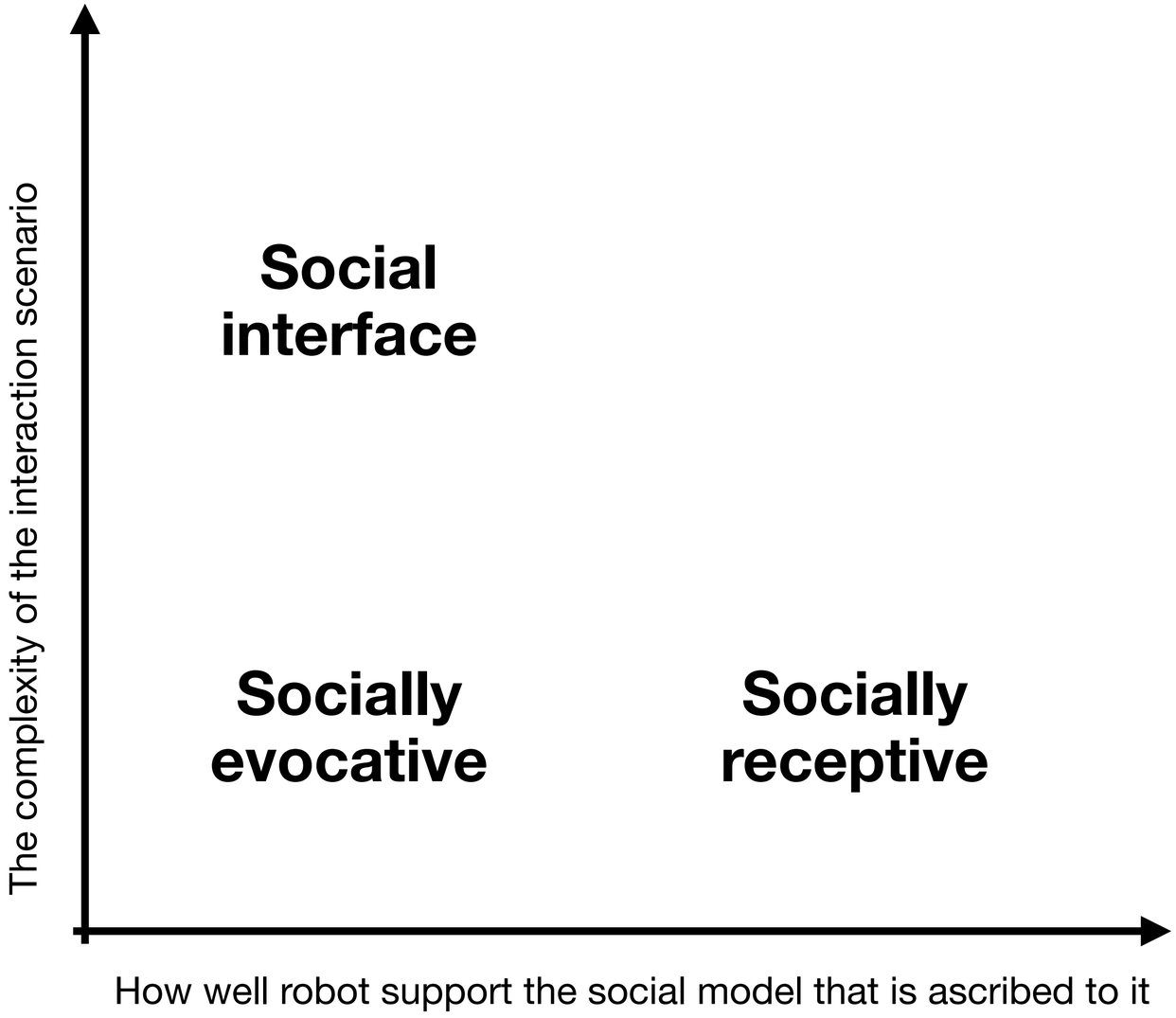
- **Socially receptive.** Robots that are socially passive but that can benefit from interaction (e.g. learning skills by imitation). Deeper models of human social competencies are required than with social interface robots.



Classes of Social Behavior

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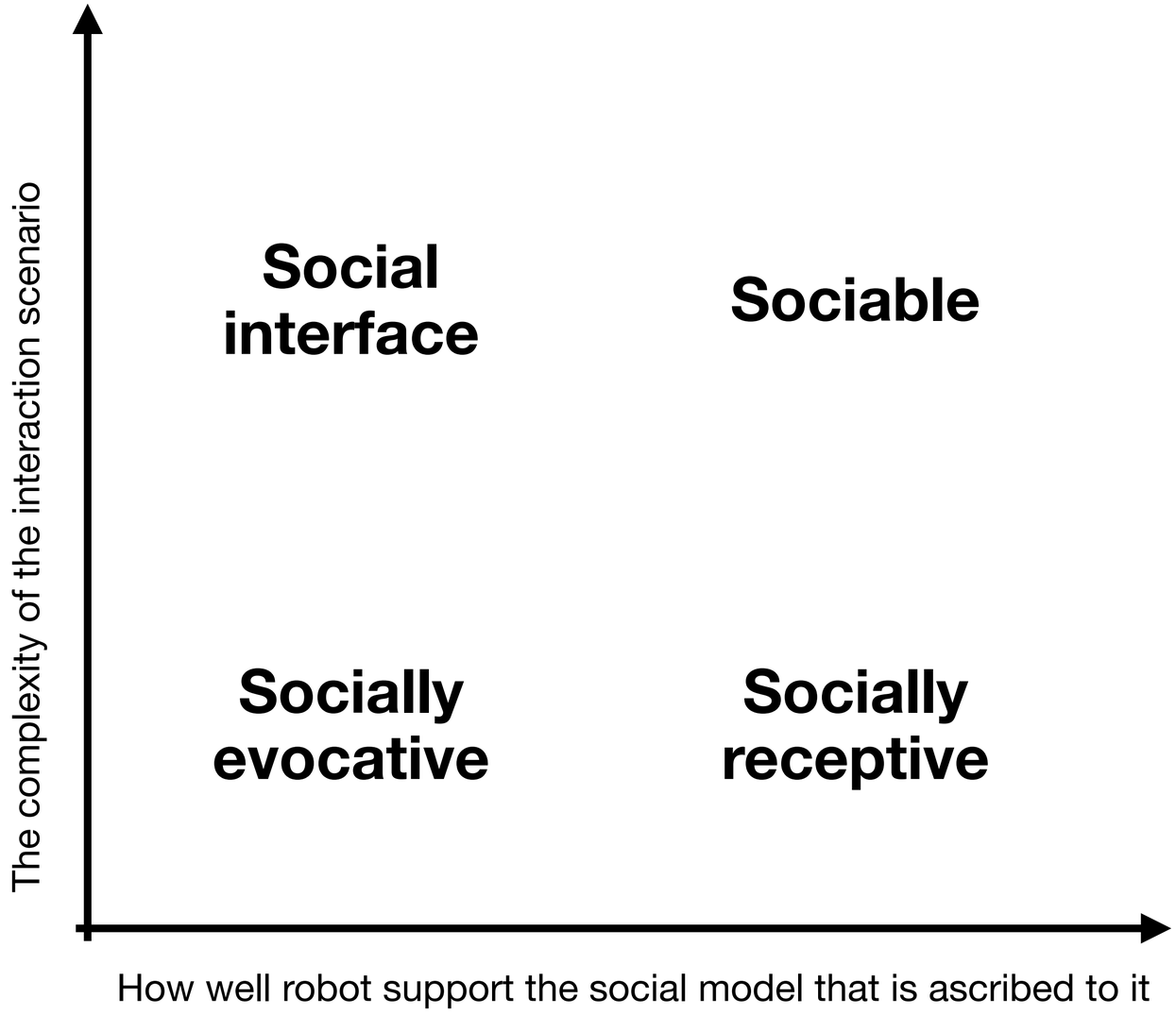
- **Sociable.** Robots that pro-actively engage with humans in order to satisfy internal social aims (drives, emotions, etc.). These robots require deep models of social cognition.



Social Embeddedness (complementary)

Dautenhahn et al., 2002; Fong et al., 2003

- **Socially situated.**
- **Socially embedded.**
- **Socially intelligent.**

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- **Socially embedded.**
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- **Socially embedded.** Robots that are: (a) situated in a social environment and interact with other agents and humans; (b) structurally coupled with their social environment; and (c) at least partially aware of human interactional structures (e.g., turn-taking).
- **Socially intelligent.**

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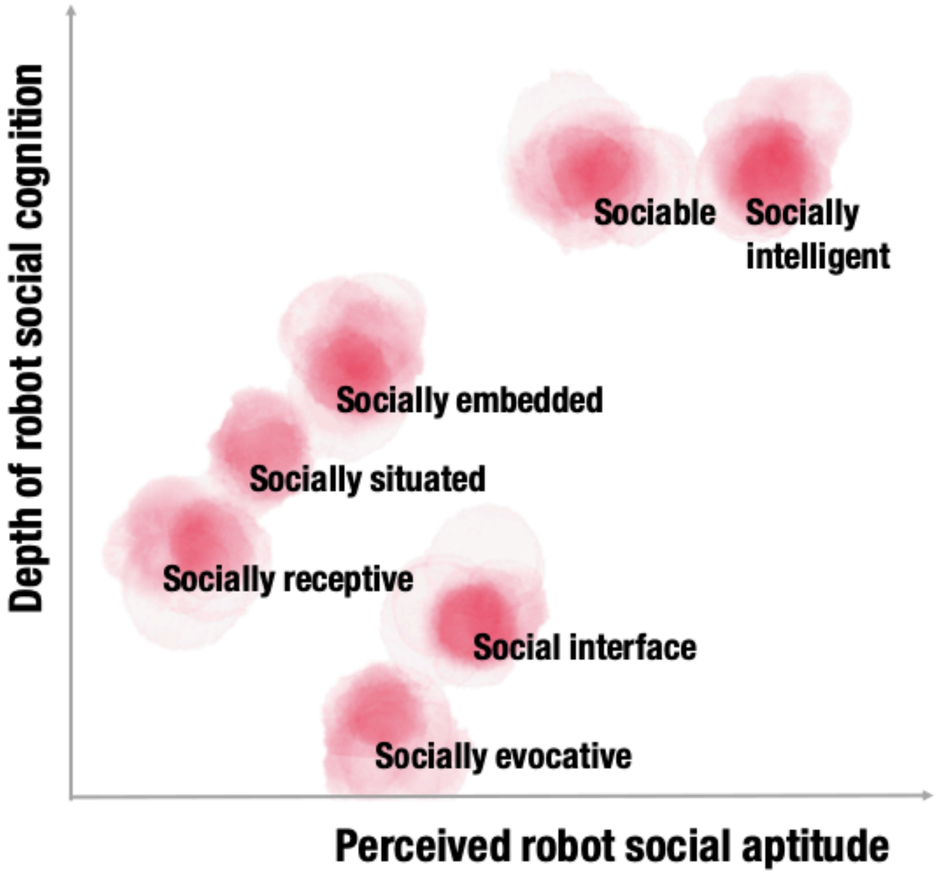
- **Socially intelligent.** Robots that show aspects of human style social intelligence, based on deep models of human cognition and social competence.

Social Capabilities

Baraka et al., 2020

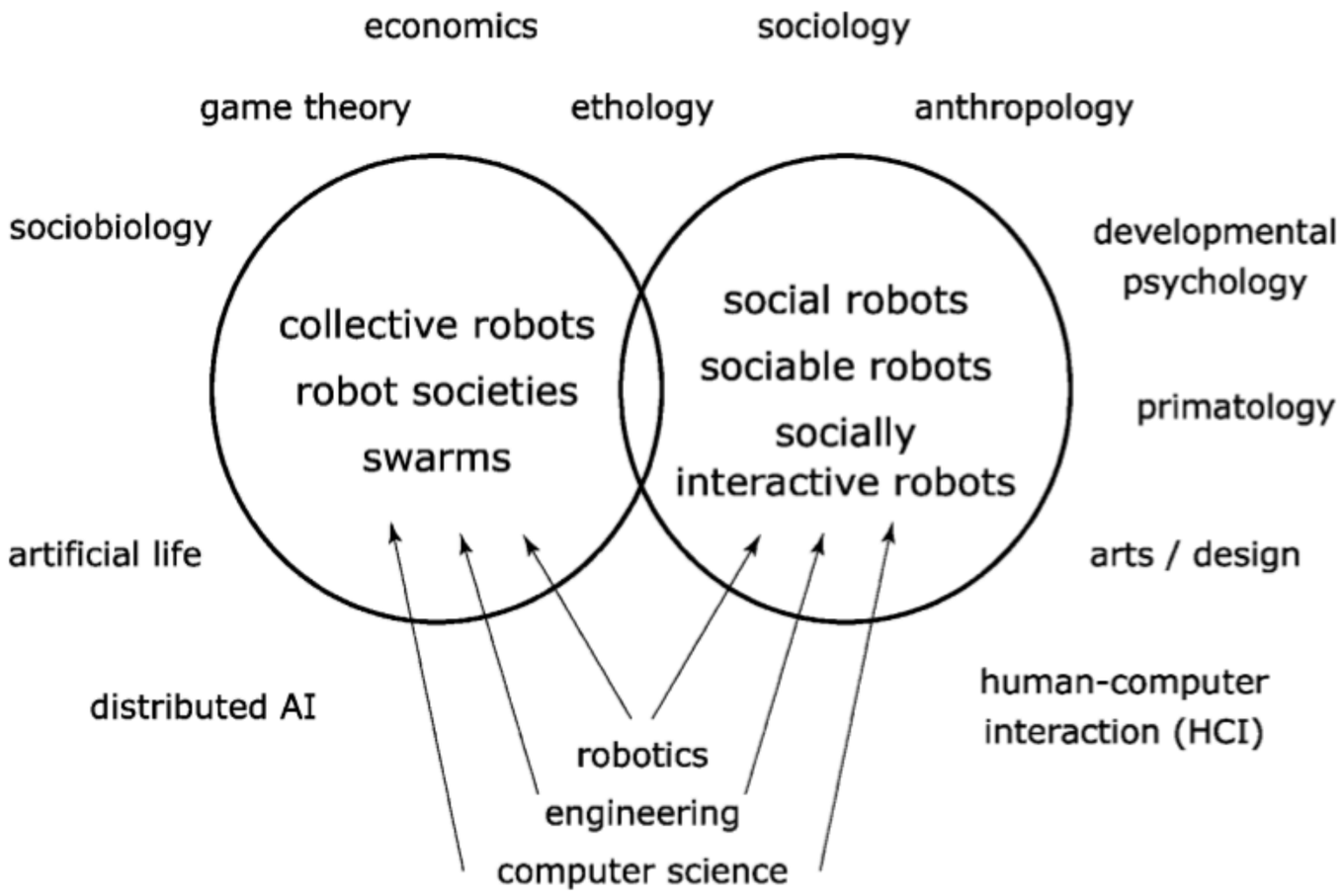
Fig. 3 Positioning of the classifications of Breazeal [32] and Fong et al. [70] according to our proposed two-dimensional space formed by (1) the depth of the robot's social cognition mechanisms, and (2) the expected human-perceived level of robot social aptitude. This figure is merely illustrative and color patches deliberately fuzzy, as we do not pretend to have the tools to actually quantify these dimensions according to any scale.



Human-Robot Interaction (HRI)

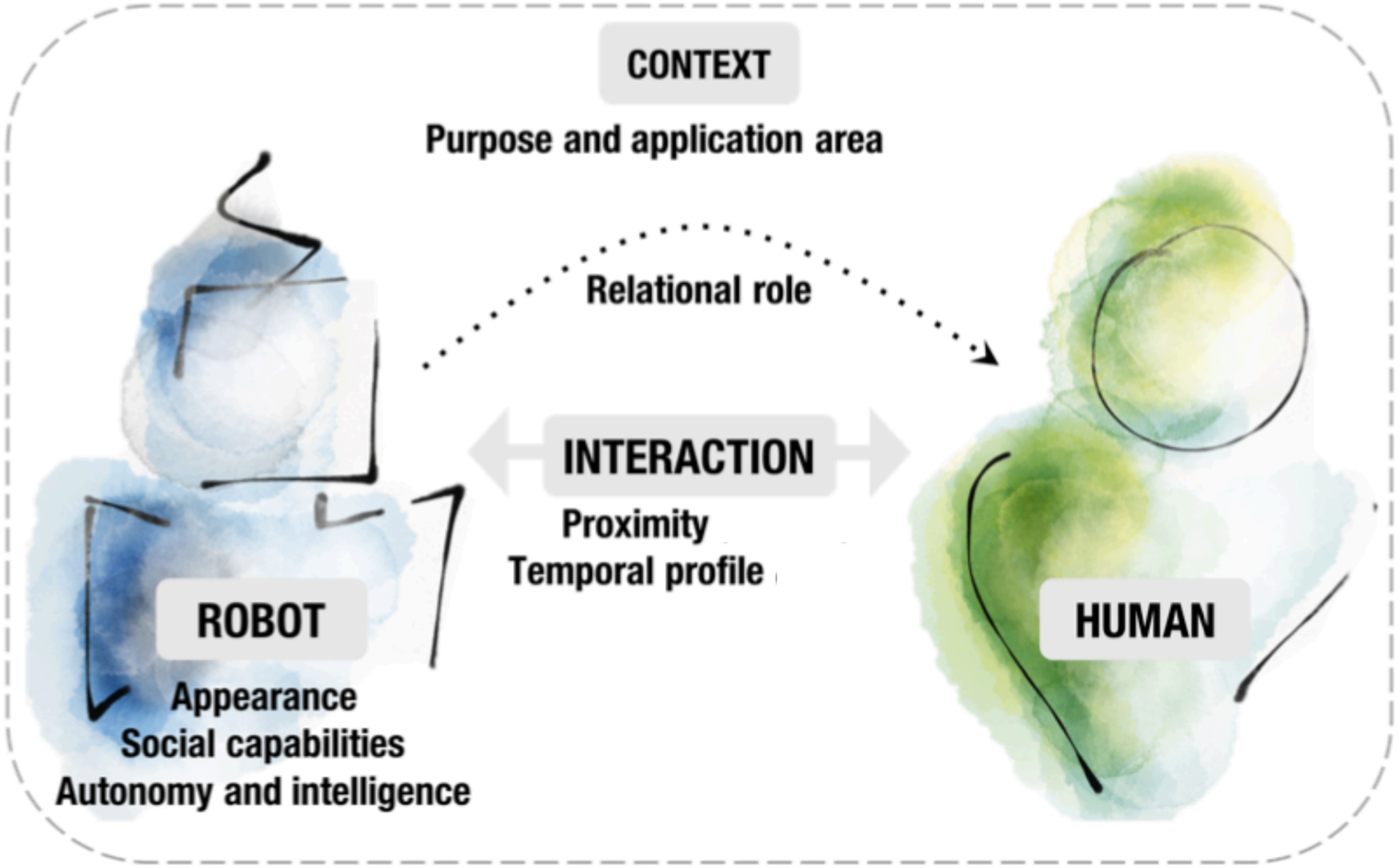
HRI - Multidisciplinary field

Fong et al., 2003



HRI - Dimensions

Baraka et al., 2020



Purpose and Application Area

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Baraka et al., 2020

Public service

Robovie in a shopping mall [170]

Roboceptionist at department reception [79]

Pepper at a store entrance

Robotinho on a museum tour [63]

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Cog used to study human cognition

Robota used to study child development [53]

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Baxter being synesthetically taught in a factory

Locusbots™ collaboratively operating in a warehouse

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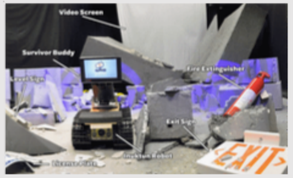

Survivor buddy/Inuktun in a simulated disaster environment [181]

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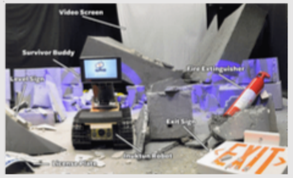

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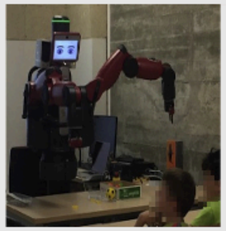
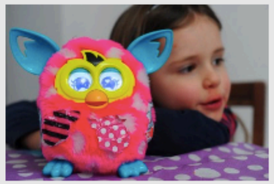
Education, entertainment and art



Baxter teaching children [67]

Bee-bot used for educational activities

HERB acting in a play [209]



Furby with a child

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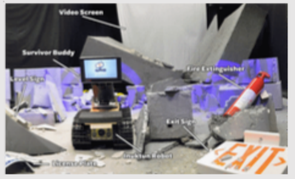

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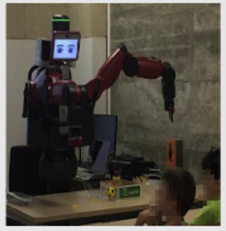

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Healthcare and therapy

NAO and child with ASD interacting [16]

Paro emotionally assisting the elderly [168]

Baxter assisting a blind person [31]

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Pearl assisting an elder person [147]

SeRoDi assisting an elder person

Robear carrying a patient

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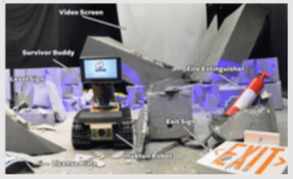

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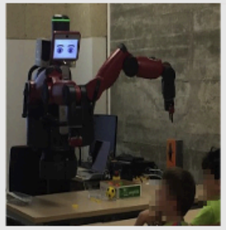

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Home and workplace

CoBot navigating an office corridor [19]

Care-O-bot 4 in a home

Bossa Nova's supermarket robot

HERB engaging in kitchen tasks

Purpose and Application Area

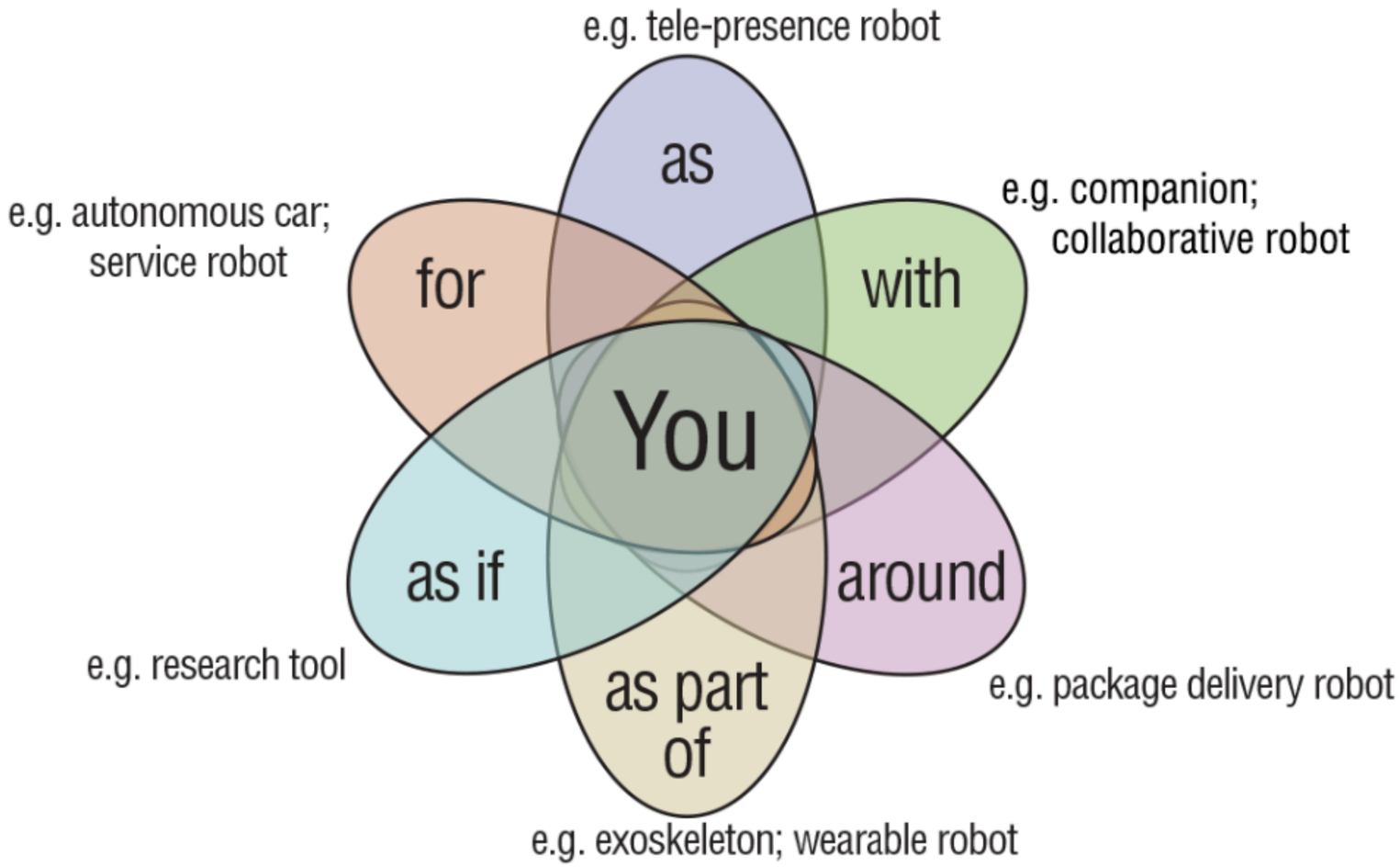
Dautenhahn, 2003

Application Domain	Contact with Humans	Functionality of the robot	Role of the robot in the society	Requirements on the social skill
Surveillance, sorting, underwater, inspecting and renovating in hazardous environments or space.	Almost none	Clearly defined	Machines used as tools and mostly outside the human occupied environments, (in dangerous ones or inaccessible by humans	Very little (so far)
Refueling, agriculture and forestry, construction, industry, cleaning and firefighting	Very little and brief (so far)	Clearly defined with interfaces to operators	Machines that automate work previously done by humans	So far, little requirement
Office, medicine, hotel and cooking, marketing.	Yes. Some. And important for the acceptance by the humans	Clearly defined	Machines in human-inhabited environments that provide services	Some needed for the acceptance by the humans.
Entertainment, hobbies and recreation	Believability and appearance of robot important.	Moderately defined. Needs to learn and adapt to the human.	Social robots that are individualised and establish social relations	Social skills of the robot and attachment of user are important to consider.
Nursing, care, therapy and rehabilitation	Close contact with humans	Non-social functionalities often clearly defined, but depending on the social functionality.	Social robots that are individualised, autonomou, which can be therapy partners or therapeutic playmates	Social skills of the robot and acceptance very important. Safety and ethical issues also important.

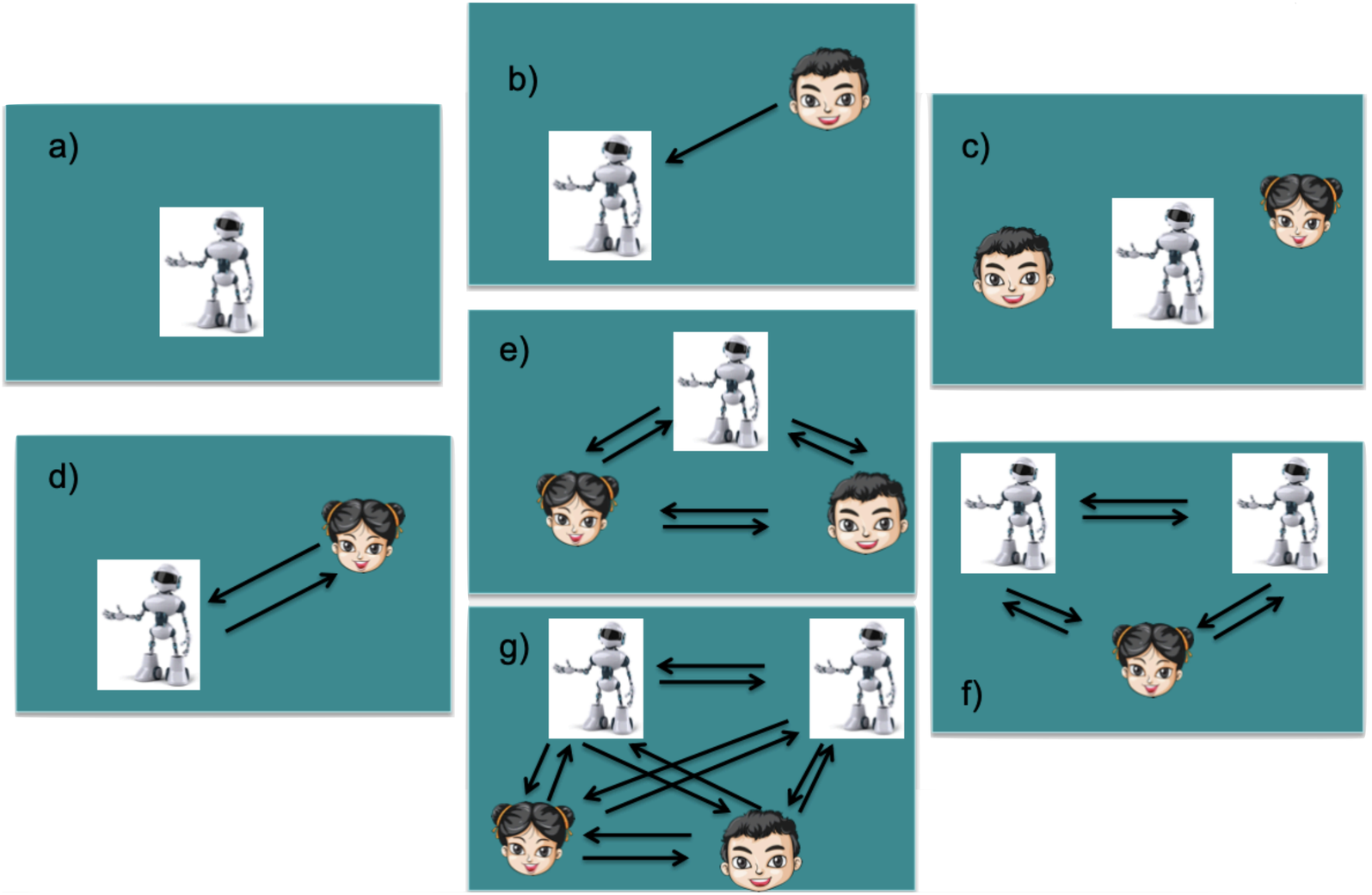
Relational Role

Relational Role

Baraka et al., 2020



Relational Role (topology)



Proximity

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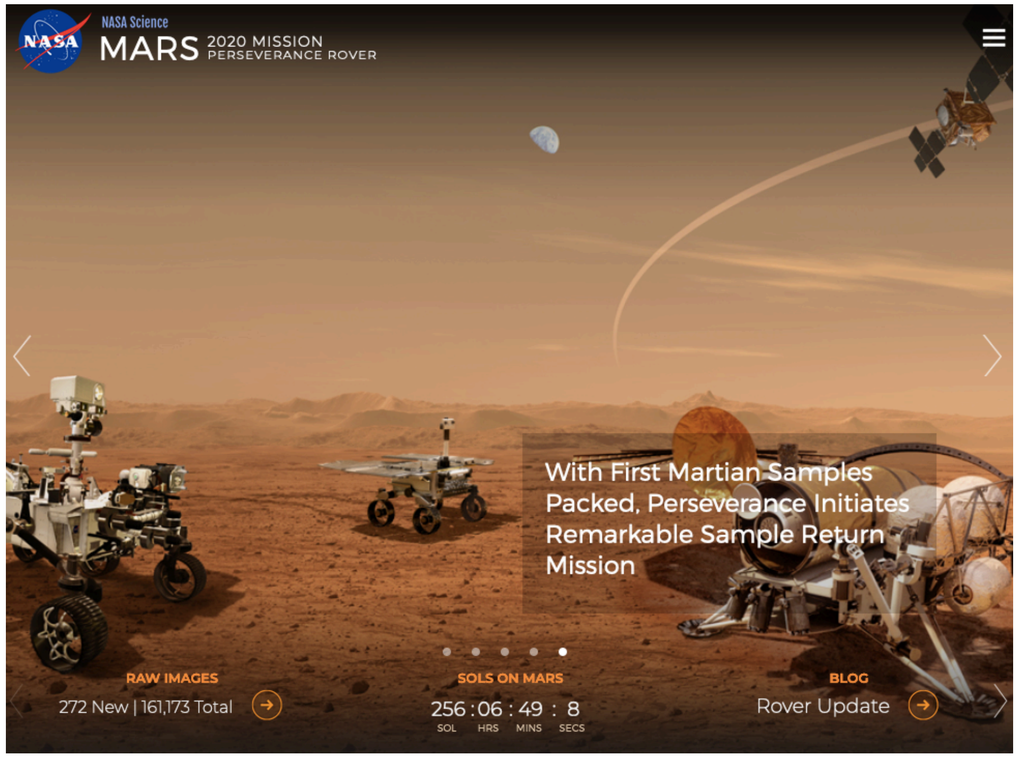
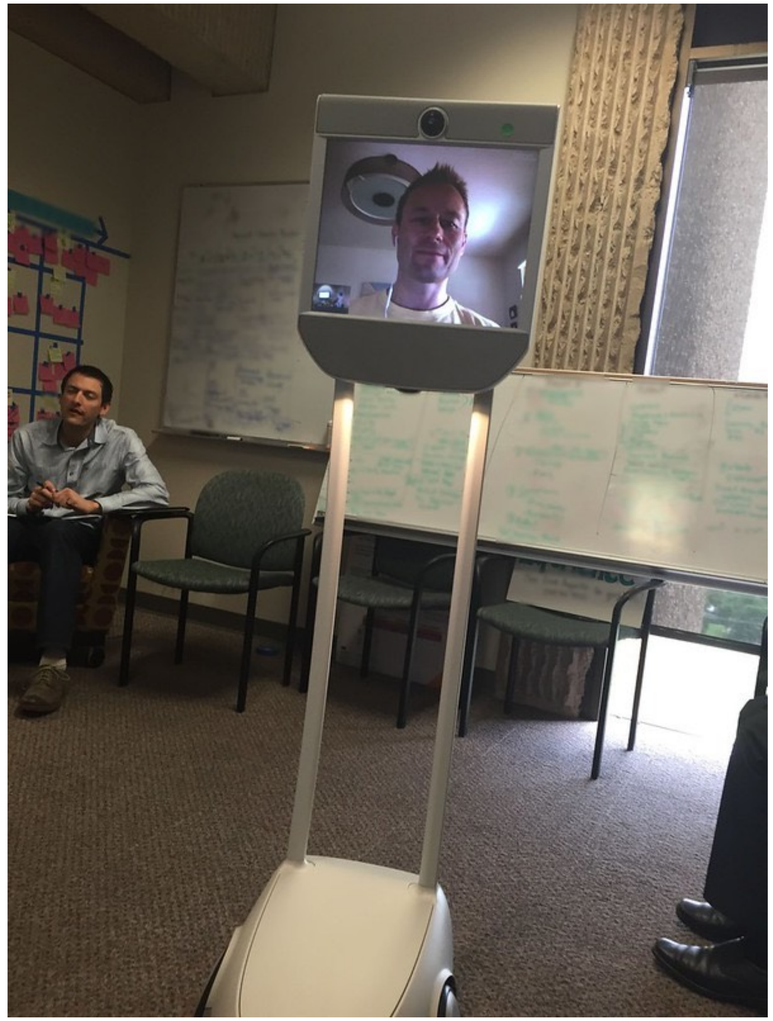
- **Remote interaction**
  - Separated spatially or even temporally





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- **Remote interaction**
  - Separated spatially or even temporally
- **Co-located interaction**
  - Without explicit physical contact

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- **Co-located interaction**
  - Without explicit physical contact
- **Physical interaction**

Healthcare and therapy

Paro emotionally assisting the elderly [168]

Baxter assisting a blind person [31]

Robear carrying a patient

Proximity

- **Remote interaction**
  - Separated spatially or even temporally
- **Co-located interaction**
  - Without explicit physical contact
- **Physical interaction**
- **Deep interaction**
  - Humans and robots become one entity

Temporal Profile

Temporal Profile

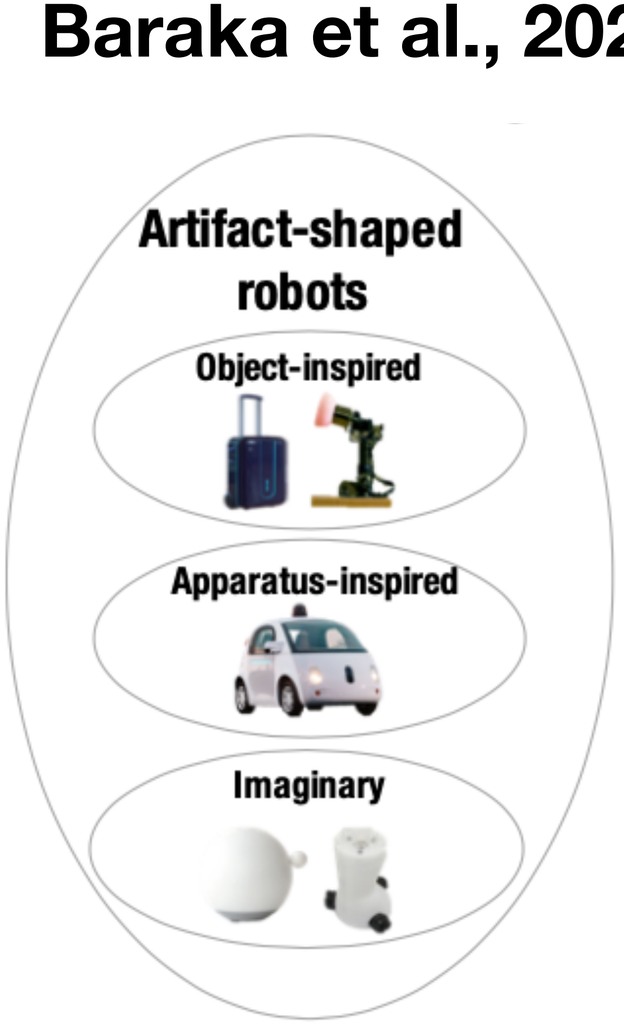
- Short-term
  - Minutes, Hours
- Medium-term
  - Days, Weeks
- Long-term
  - Months, Years
- Life-long
  - The human may go through large changes, e.g., transitioning from childhood to adulthood

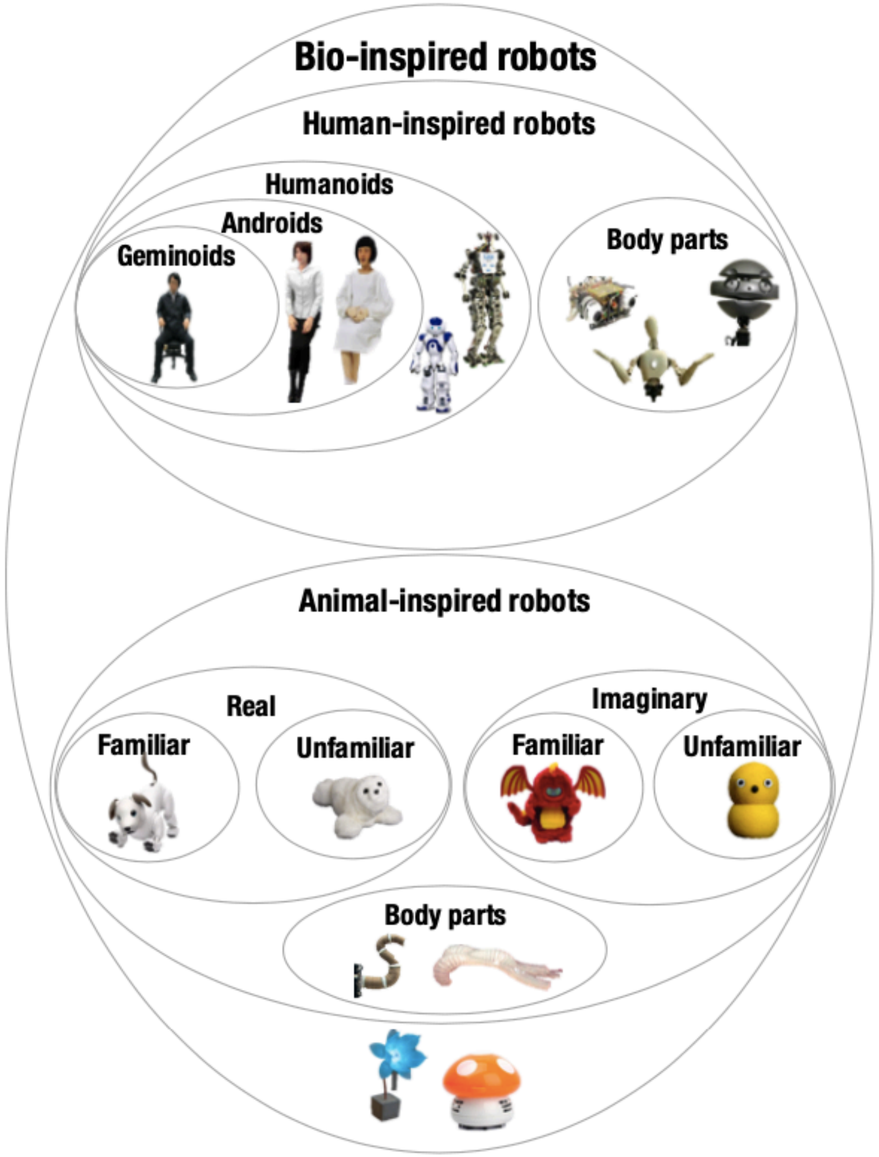
Breaking the novelty effect!

Robot Appearance

Robot Appearance

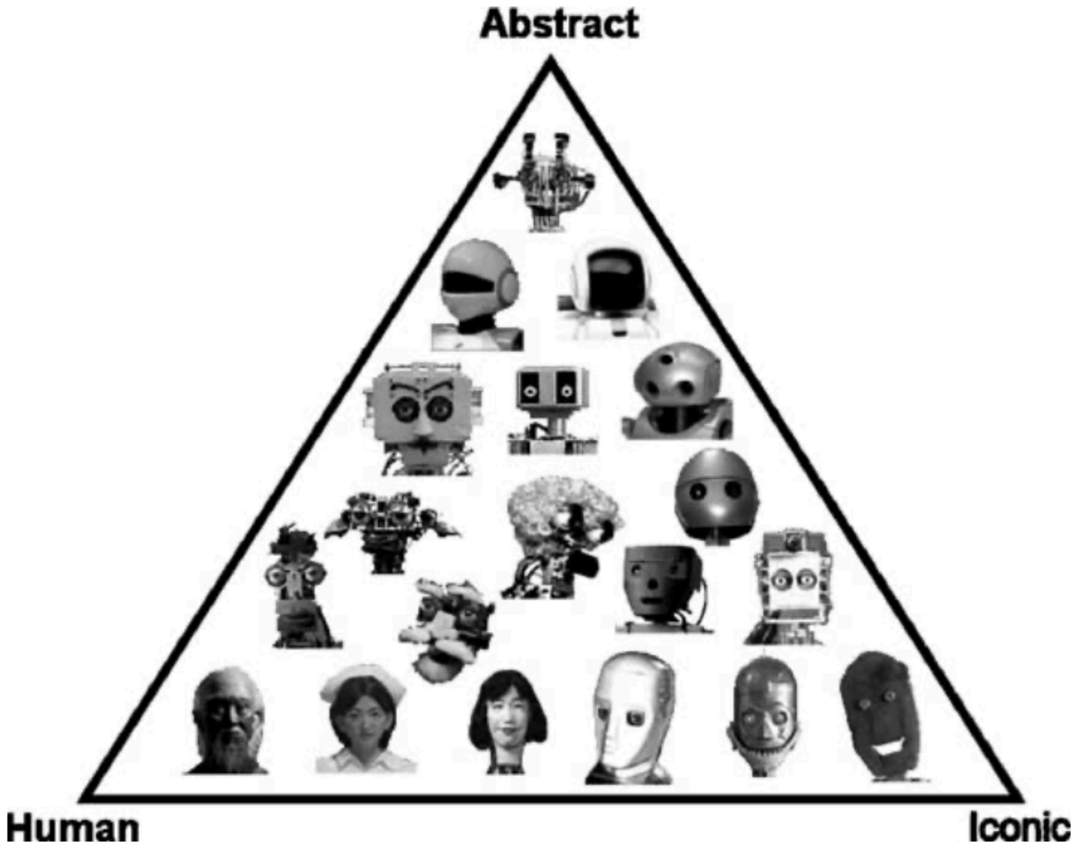
Baraka et al., 2020





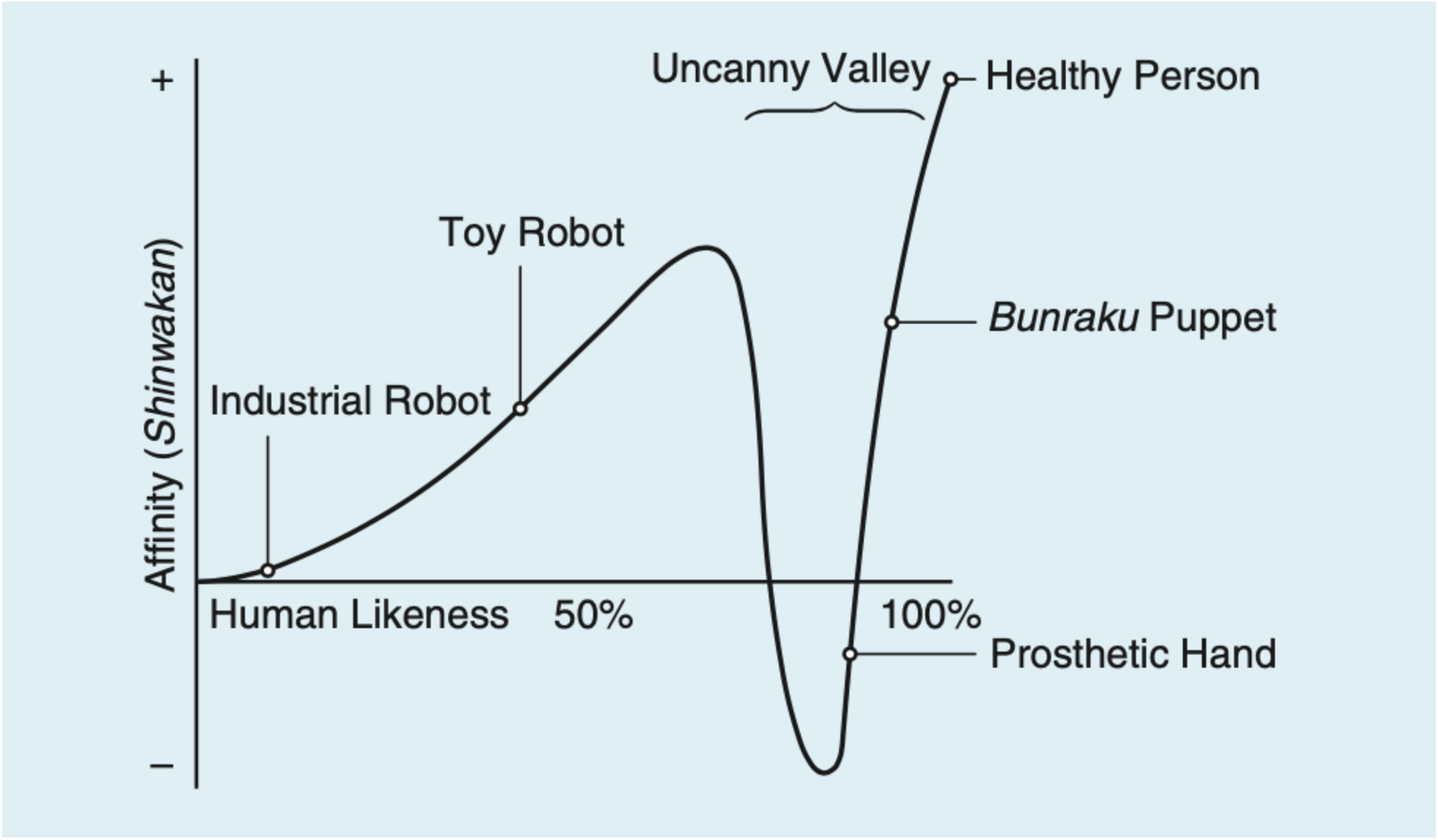
Robot Appearance - Humanlikeness

Duffy, 2003



Robot Appearance - Uncanny Valley

Mori et al., 2012



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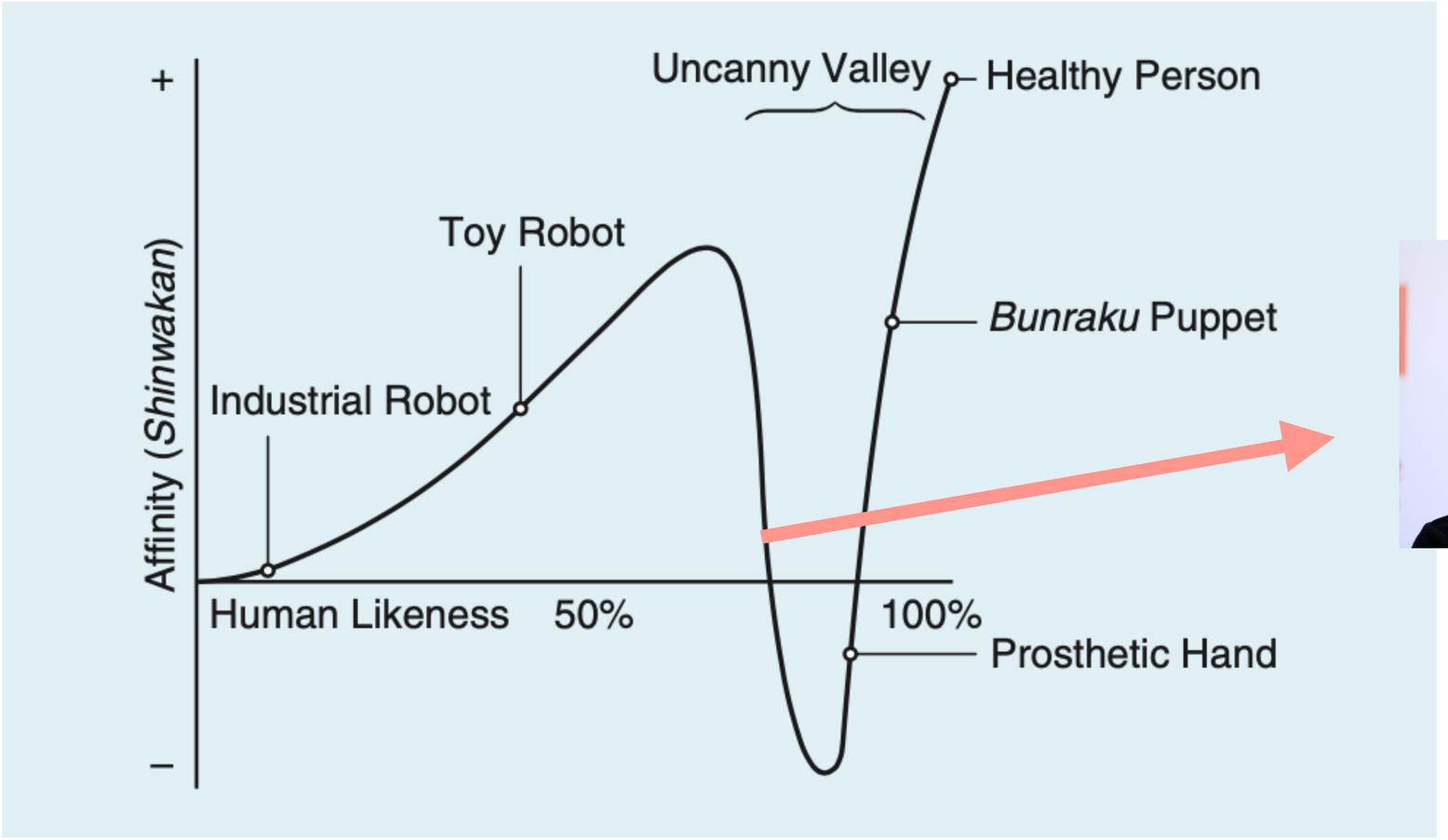
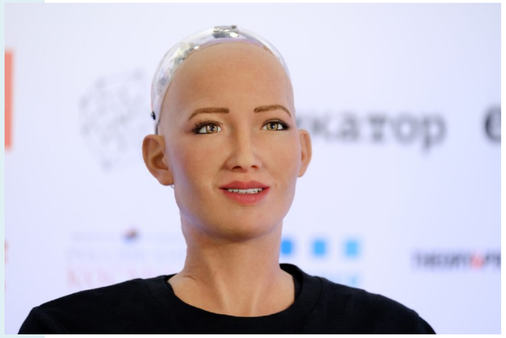




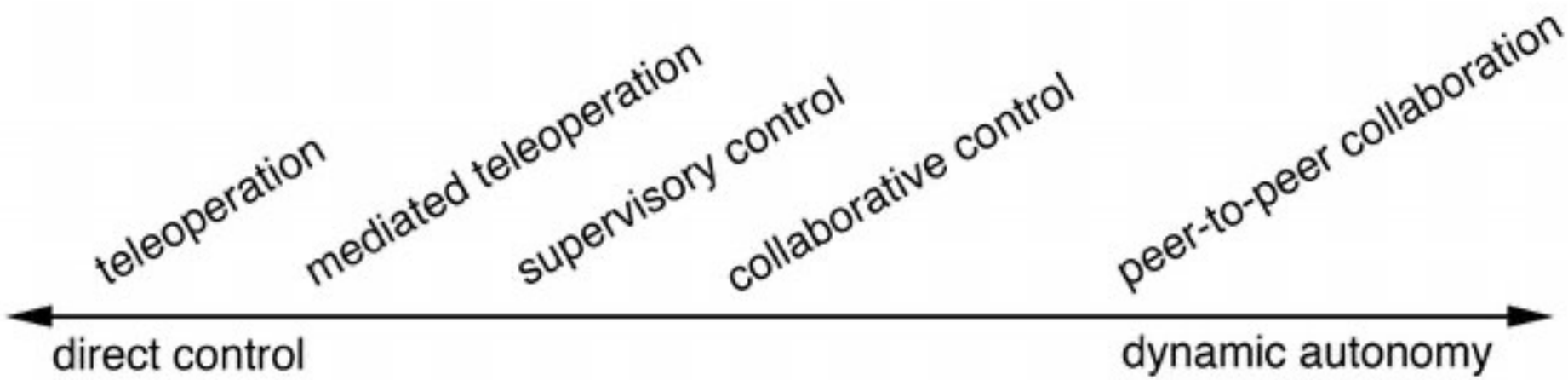
Autonomy and Intelligence

Autonomy

“The extent to which a robot can operate in the tasks it was designed for without external intervention.”

Autonomy

Goodrich & Schultz, 2008



Autonomy - Sheridan’s Scale

Sheridan, 1978

1. Computer offers no assistance; human does it all
2. Computer offers a complete set of action alternatives
3. Computer narrows the selection down to a few choices
4. Computer suggests a single action
5. Computer executes that action if human approves
6. Computer allows the human limited time to veto before automatic execution
7. Computer executes automatically then necessarily informs the human
8. Computer informs human after automatic execution only if human asks
9. Computer informs human after automatic execution only if it decides to
10. Computer decides everything and acts autonomously, ignoring the human

Social Capabilities

Social Capabilities

Fong et al., 2003

According to Fong et al. a social robot can exhibit the following “human social” characteristics:

1. express and/or perceive emotions;
2. communicate with high level dialogue;
3. learn/recognise models of other agents;
4. establish/maintain social relationships;
5. use natural cues (gaze, gestures, etc.);
6. exhibit distinctive personality and character;
7. may learn/develop social competencies.

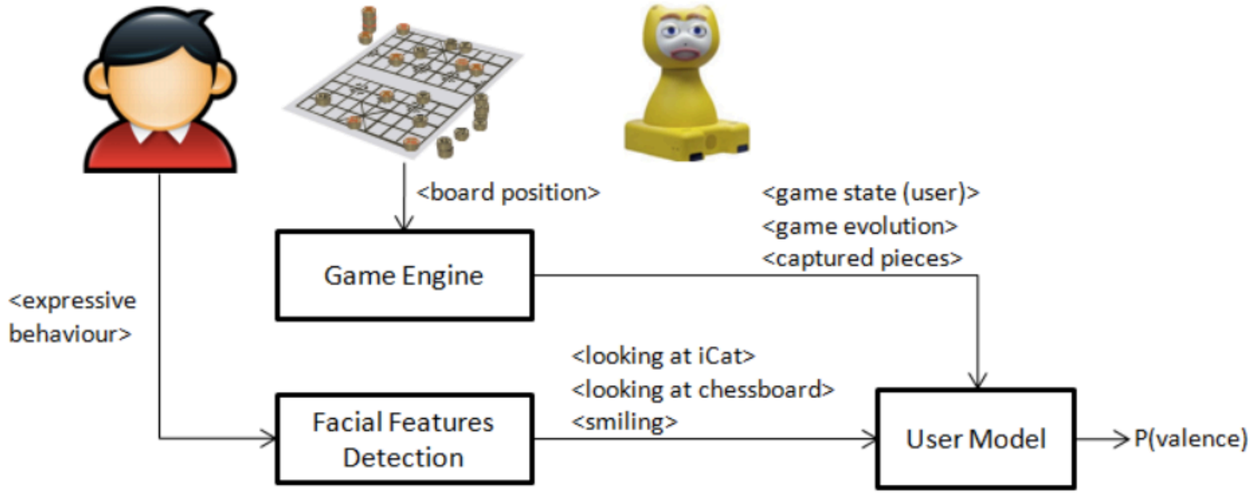
Social Capabilities

1. Express and/or perceive emotions

Leite et al., 2012

iCat the Affective Chess Player

“The results of the study suggest that children perceived the robot in both empathic versions as more engaging, helpful and also provided higher ratings in terms of self-validation.”



Social Capabilities

2. Communicate with high level dialogue

Williams & Scheutz, 2017

A reasoning component that produces human-preferred clarification requests that conform with the pragmatics of human-robot dialogue

“Our second experiment showed that the theoretical commitments of our robot architecture align with human preferences, and that the clarification requests generated by our full NLG pipeline may be comparable to human-generated clarification requests.”

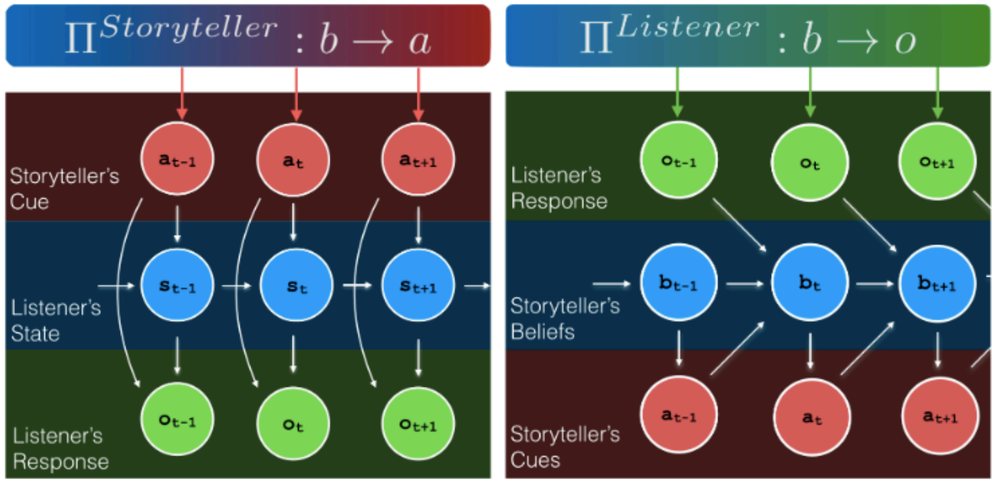
Social Capabilities

3. Learn/recognise models of other agents

Lee et al. 2019

Bayesian Theory of Mind approach to model dyadic storytelling interactions

“The role of storytellers is to influence and infer the attentive state of listeners using speaker cues, and we computationally model this as a POMDP planning problem. The role of listeners is to convey attentiveness by influencing perceptions through listener responses, which we computational model as a DBN with a myopic policy.”



(a) Intentional Inference Model (b) Belief Manipulation Model

Social Capabilities

4. Establish/maintain social relationships

Leite et al., 2013

Int J Soc Robot (2013) 5:291–308
DOI 10.1007/s12369-013-0178-y

SURVEY

Social Robots for Long-Term Interaction: A Survey

Guidelines for Future Design:

- Appearance and expectations

- Incremental Novel Behaviours

- Affective Interactions and Empathy

- Memory and Adaptation

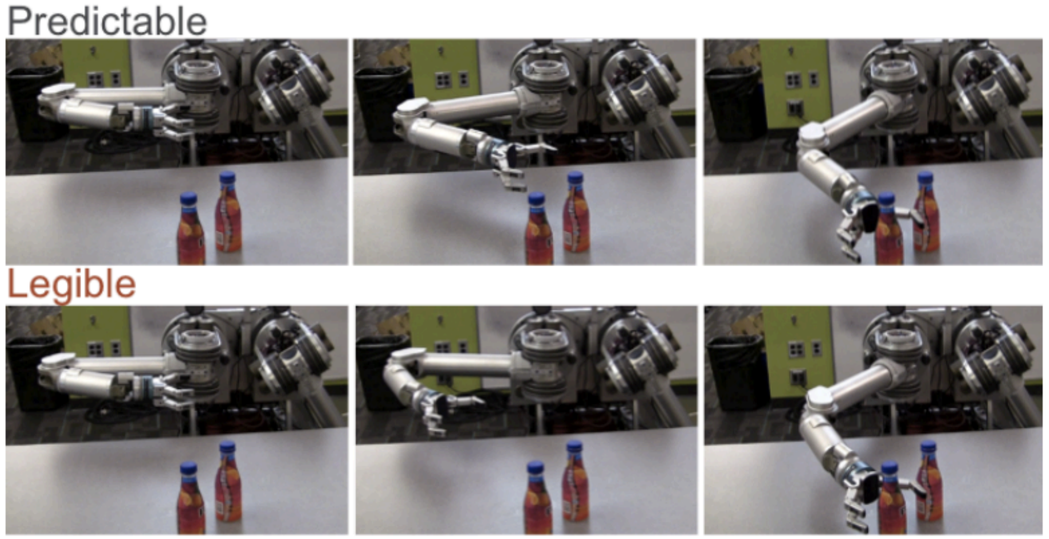
Social Capabilities

5. Use natural cues (gaze, gestures, etc.)

Dragan et al., 2013

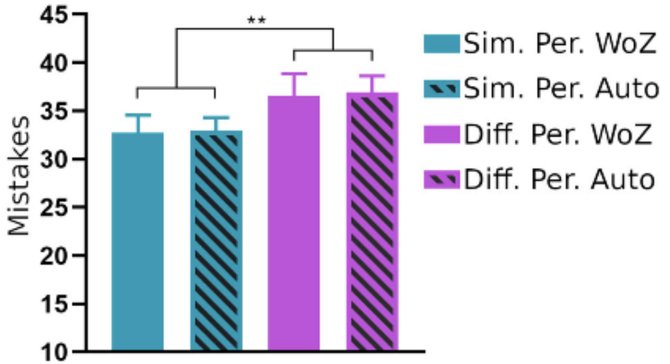
A formalism to mathematically define and distinguish predictability and legibility of motion and models to generate predictable/legible motions based on optimizing cost.

“Legible motion is motion that enables an observer to quickly and confidently infer the correct goal G. Predictable motion is motion that matches what an observer would expect, given the goal G.”



Social Capabilities

6. Exhibit distinctive personality and character



Andriella et al., 2020

Memory Game Assistive Scenario

“Our findings showed that participants were able to distinguish between robots’ personalities, and not between the level of autonomy of the robot (Wizard-of-Oz vs fully autonomous). Finally, we found that participants achieved better performance with a robot helper that had a similar personality to them, or a human helper that had a different personality.”

Social Capabilities

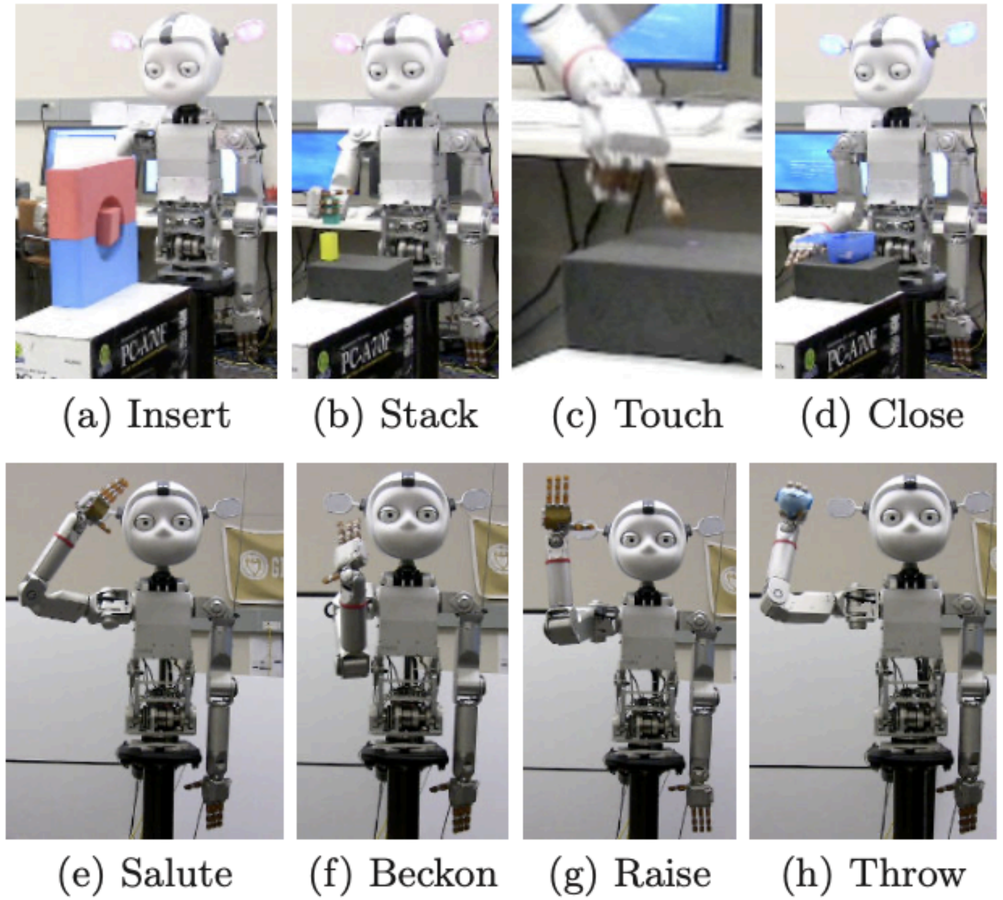
7. May learn/develop social competencies

Akgun et al., 2012

Learning by Demonstration

The paper explores three demonstration approaches. Human teachers can demonstrate skills to the robot in three different ways: trajectory demonstrations, keyframe demonstrations, and keyframe iterations.

“Finally, based on these observations, we introduced a hybrid mode of interaction in which the user can chain together keyframe and trajectory segments.”



Computational Models for Human-Robot Teams in Multiparty Settings

- A Model of Group-based Emotions

What are Group-based Emotions?

No attribution of membership

Individual-based Emotions

Attribution of membership to that social group

+

Event is relevant for a social group

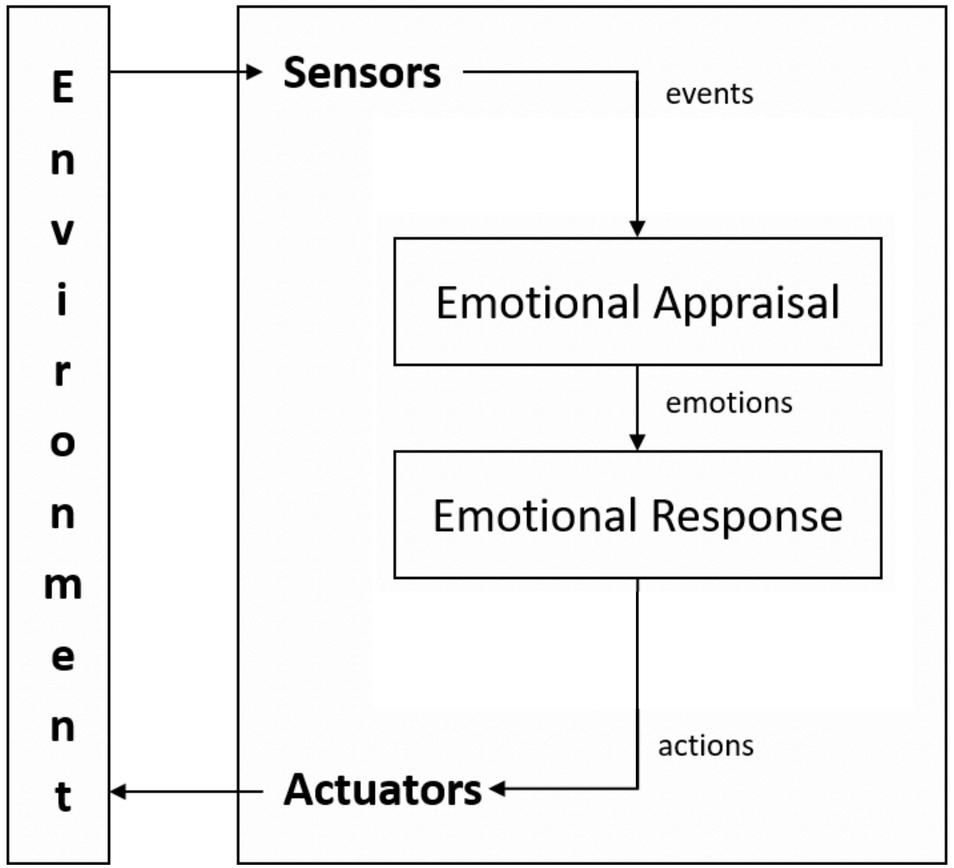
↓

Group-based Emotions

Motivation

- Cohesion of the social group (interpersonal relations)
- Trust and Group Identification may lead to positive team performance
- More intergroup interactions in HRI…

Current Models for Generation of Emotions



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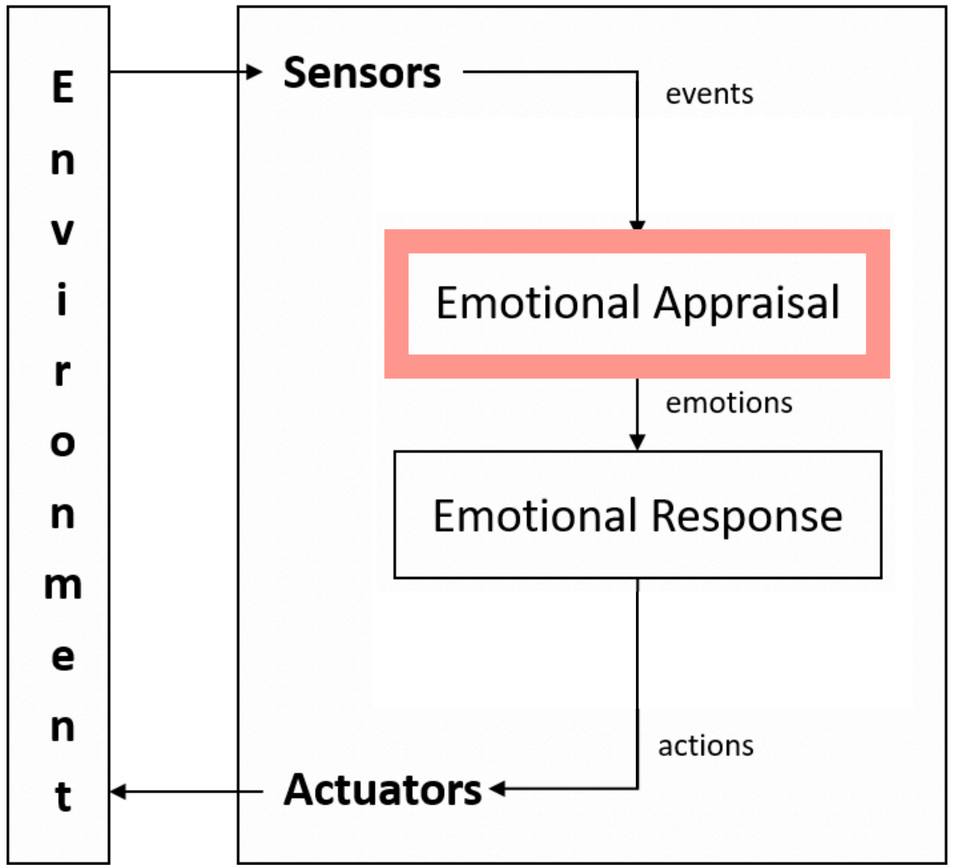

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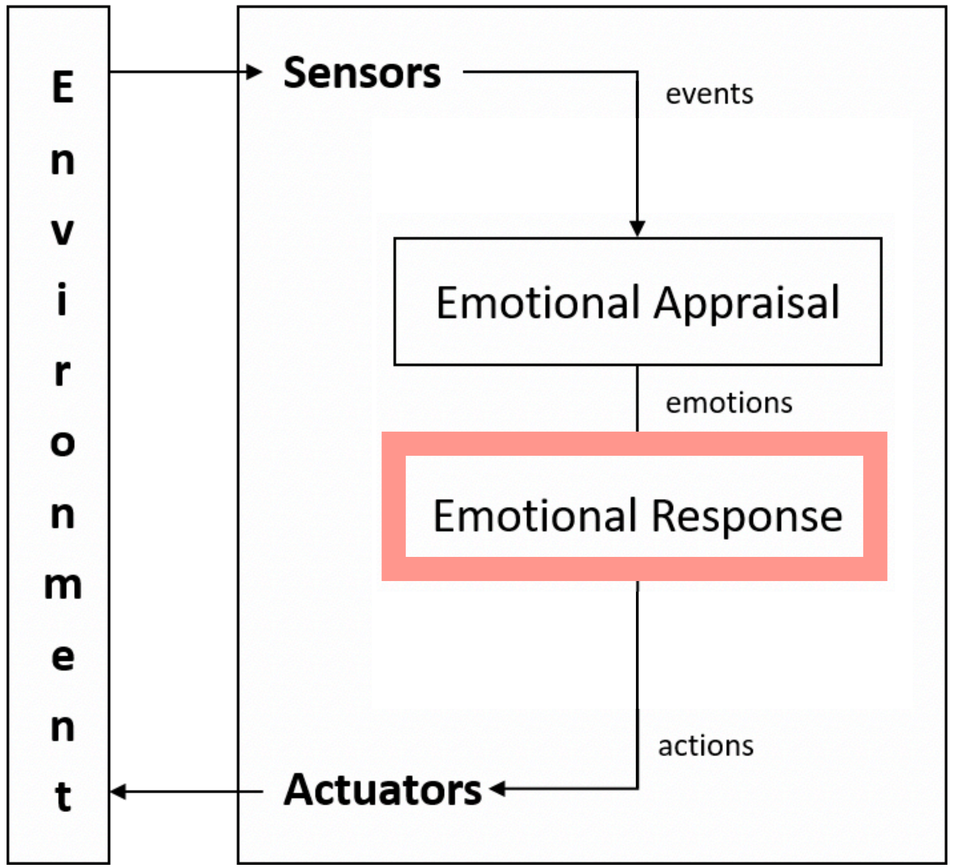
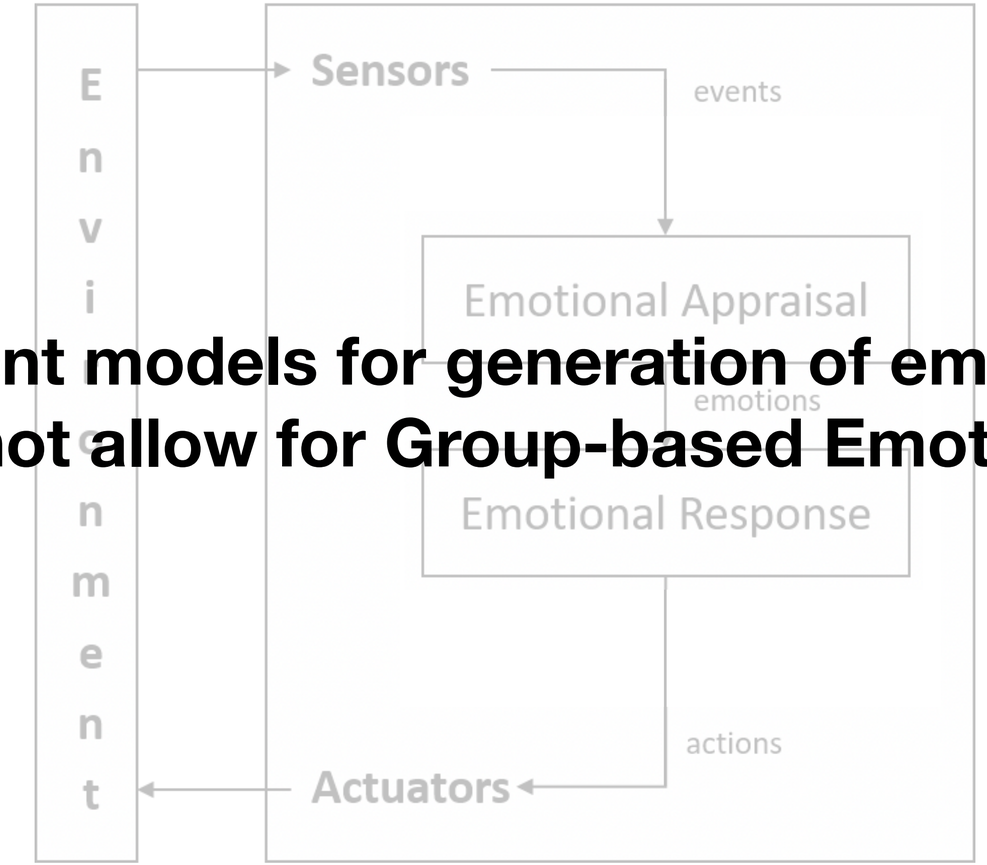


Current Models for Generation of Emotions

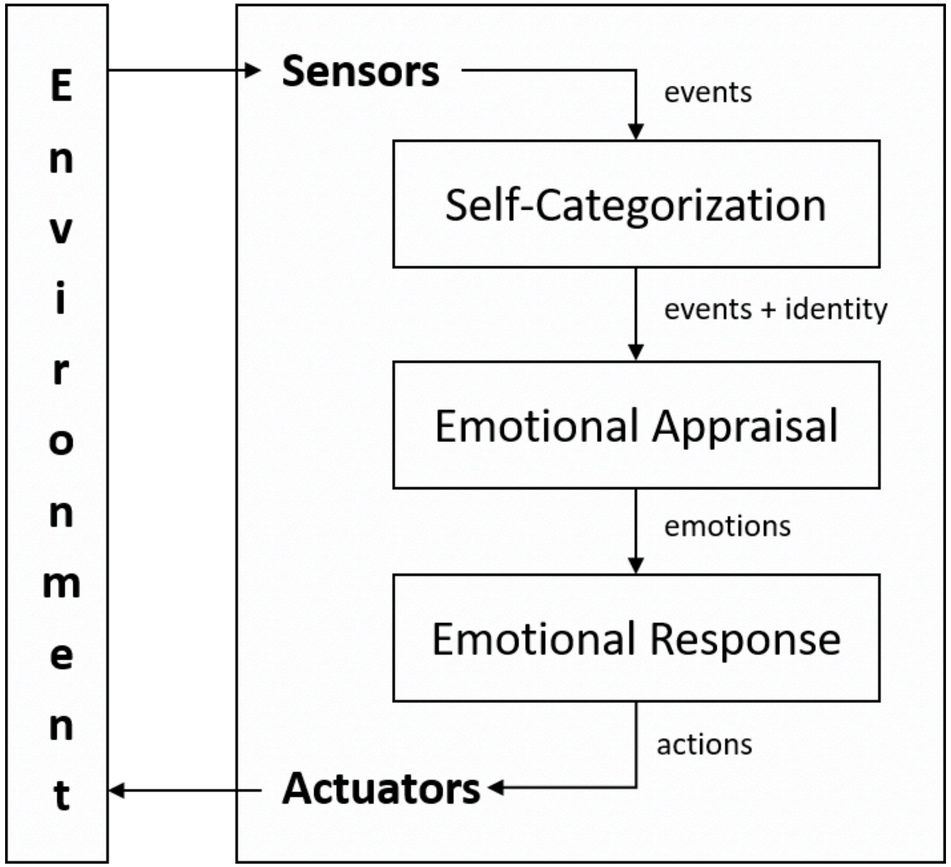


Current models for generation of emotions do not allow for Group-based Emotions!

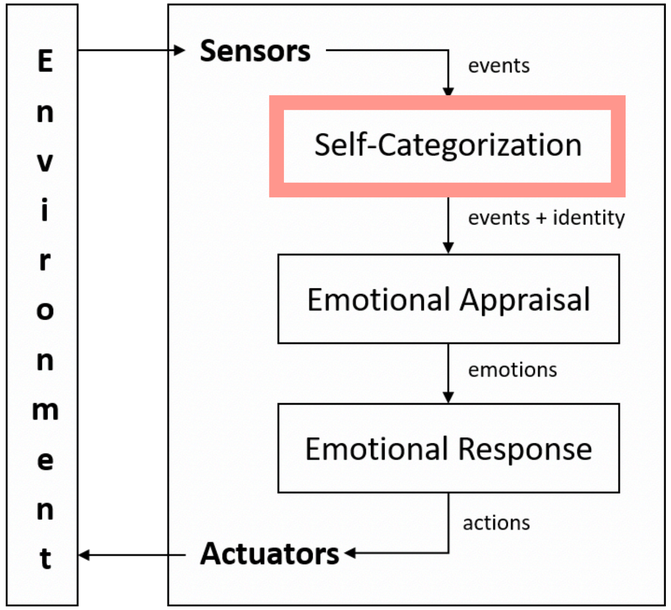
A Model of Group-based Emotions (GbE)

Goldenberg et al., 2016

Based on the psychological model of GbE



A Model for GbE in Social Robotic Characters



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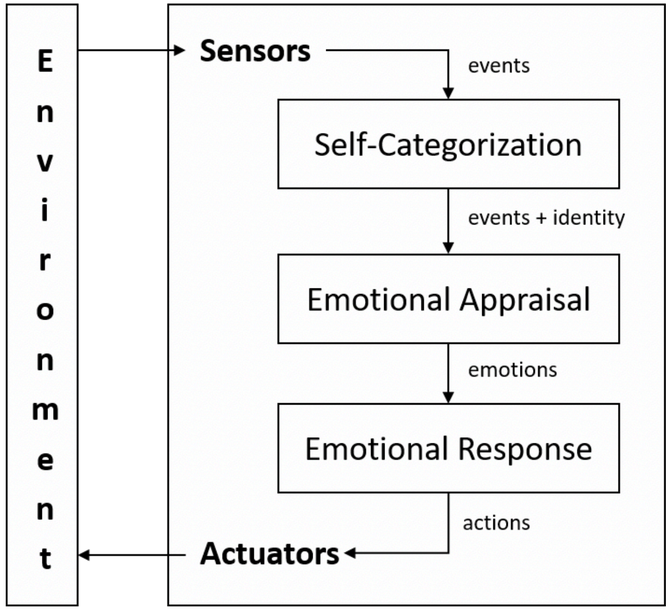


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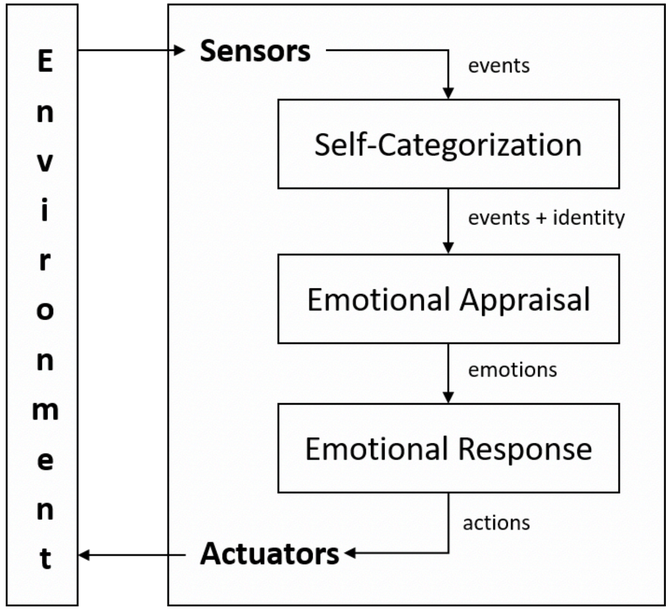


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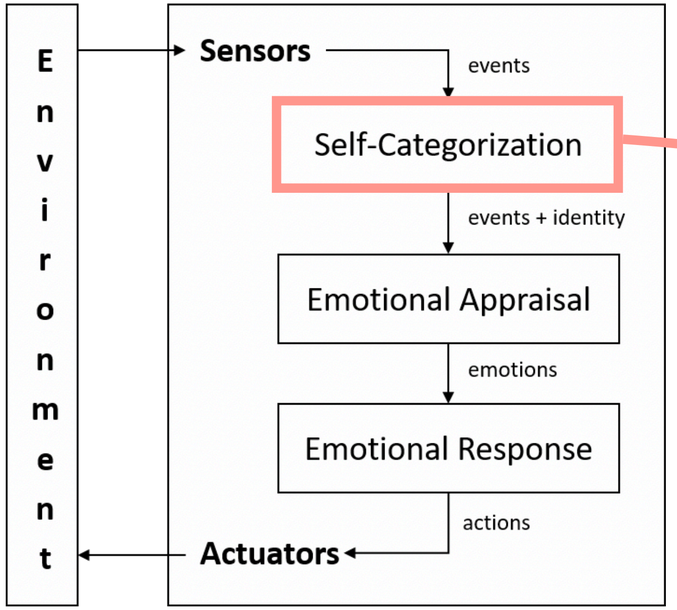


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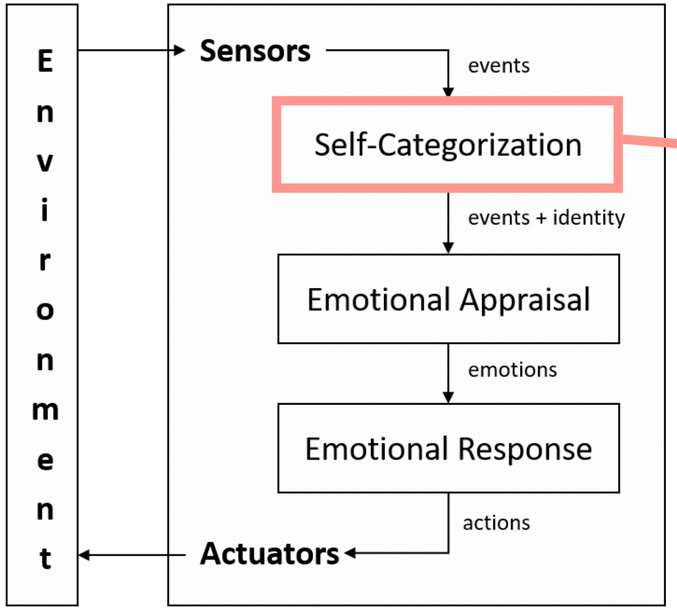


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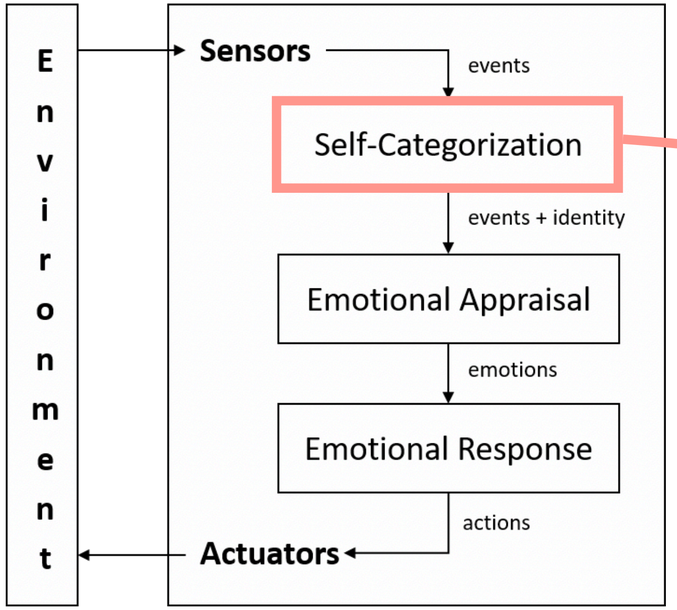


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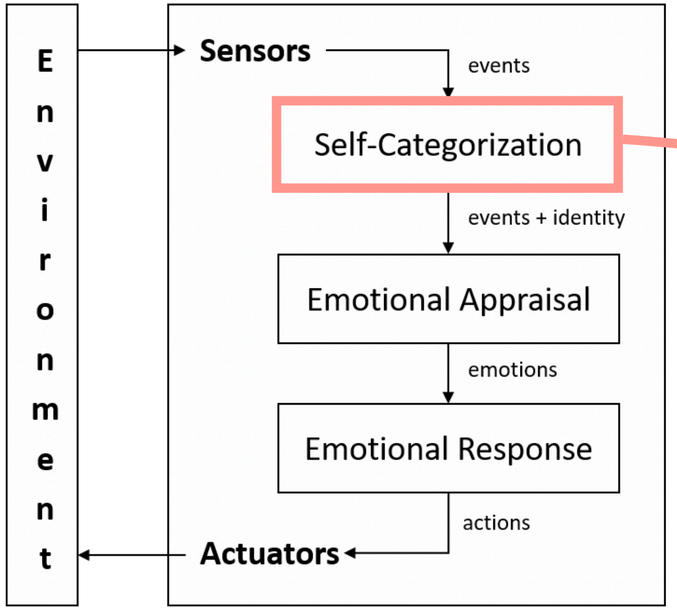


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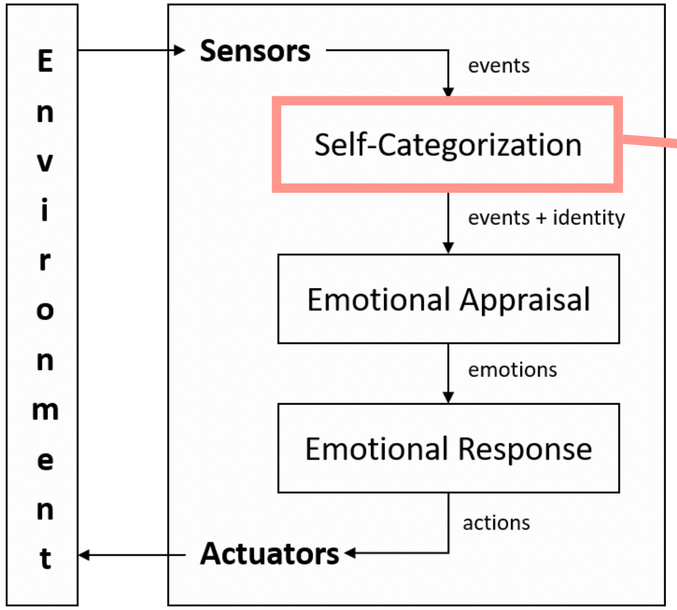


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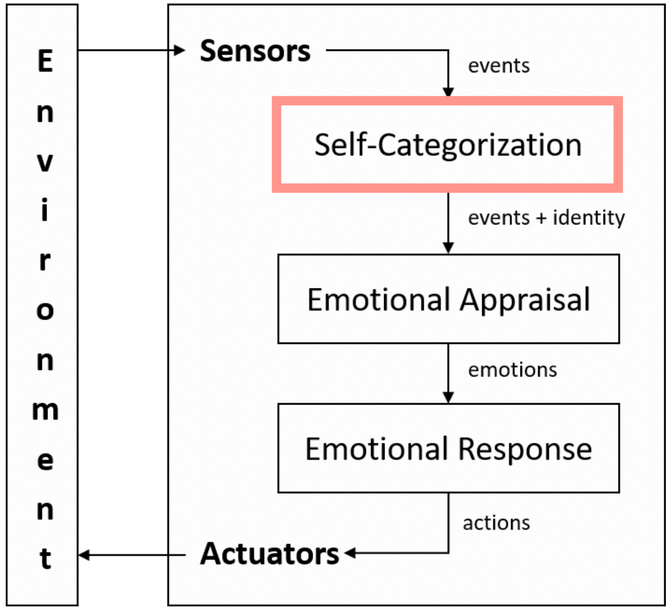


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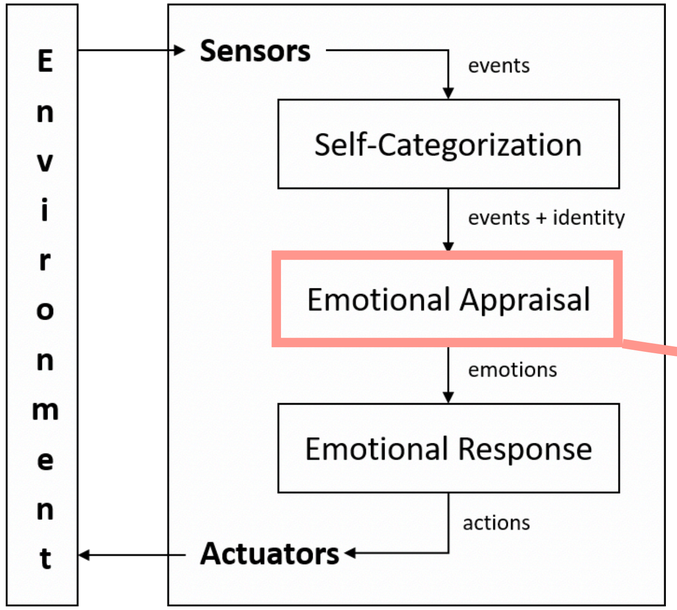


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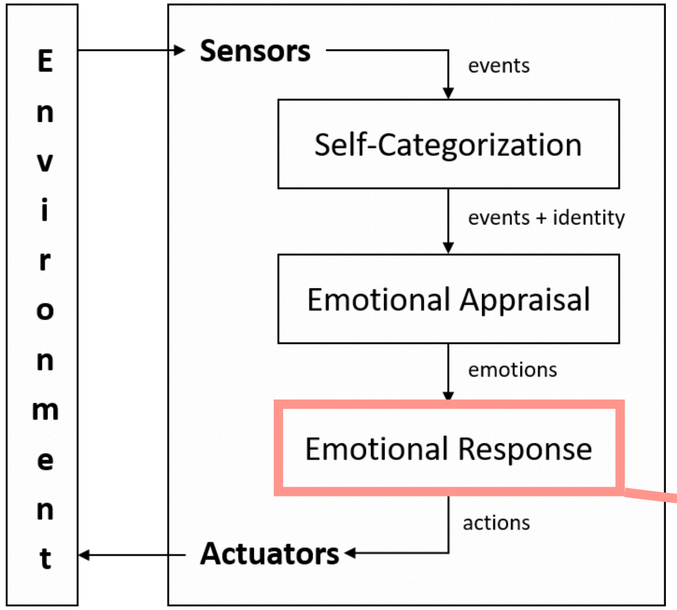


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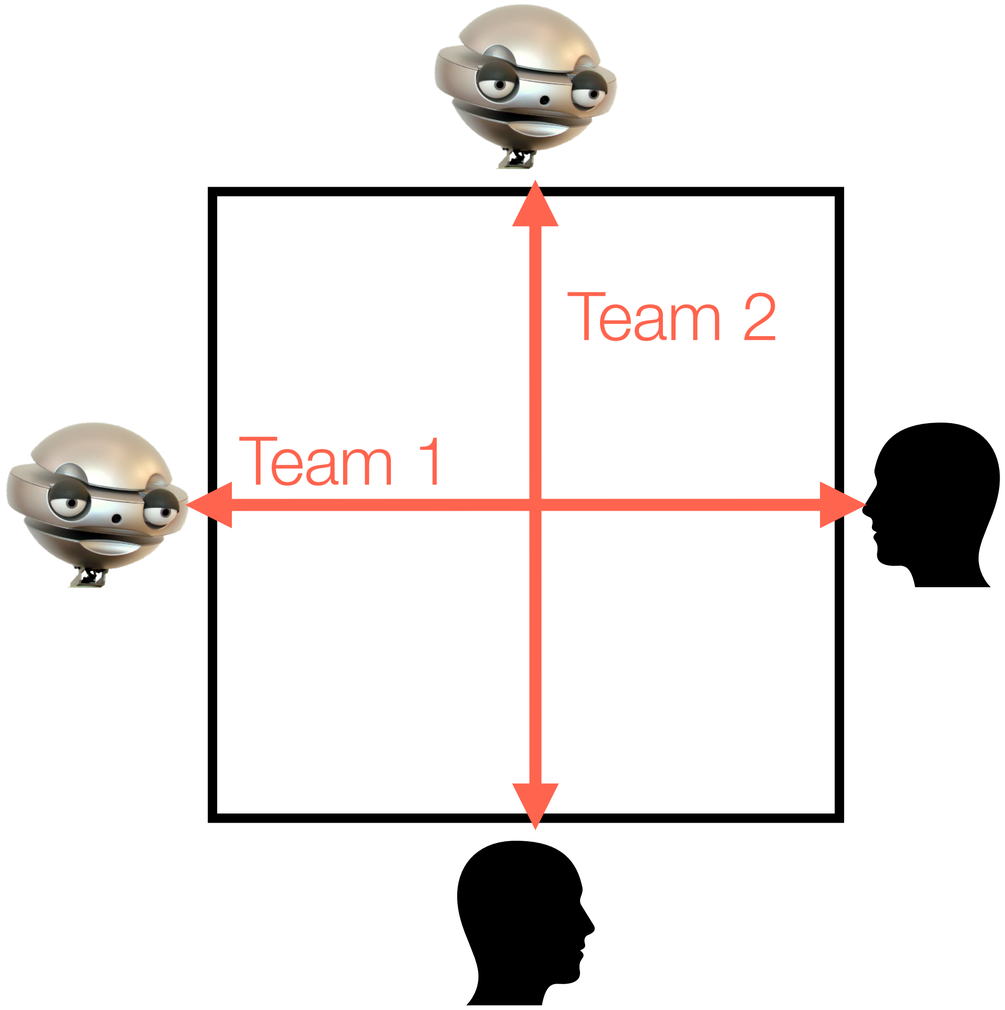
Evaluation Scenario

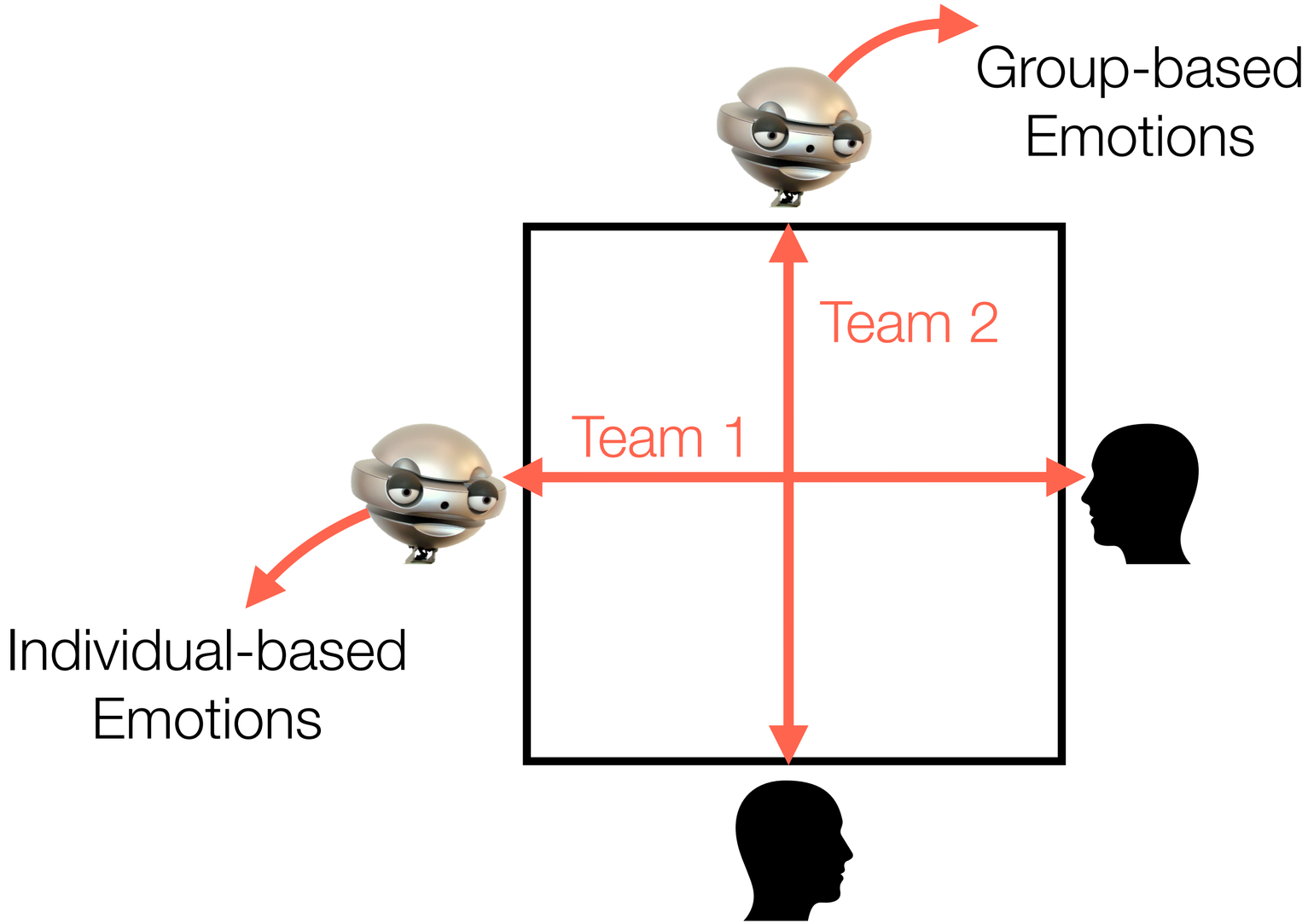
- *Sueca* game
- Trick-taking card game
- 2 adversarial teams
- Winning team is the one with more points
    - In-group
    - Out-group



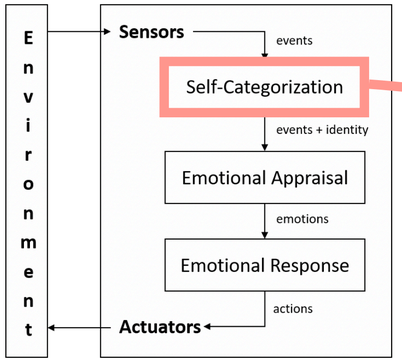
Hypotheses

- **H1**: Participants will have a stronger **Group Identification** with a robotic partner that expresses GbE.
- **H2**: Participants will have a more **positive perception** of a robotic partner that expresses GbE.
- **H3**: Participants will have a higher degree of **Group Trust** with a robotic partner that expresses GbE.

Testing Hypotheses



How?

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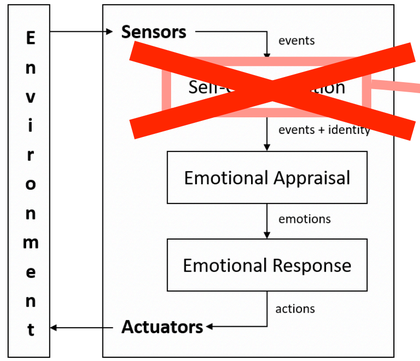
Group-based Emotions

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Individual-based Emotions

How?

Group-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Individual-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

How?

Group-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Event(P3,IncreasePoints(Trick,11))

Individual-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Event(P3,IncreasePoints(Trick,11))

How?

Group-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Event(P3,IncreasePoints(Trick,11))

{T1,T2} ← ContextManager.GetSalientSocialGroups()
T1 ← IdentityManager.SelfCategorisation(SG, self)

If P3 ∈ T1
Then,
- Event(**T1**,IncreasePoints(Trick,11))
- Self ← **T1**

Individual-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Event(P3,IncreasePoints(Trick,11))

How?

Group-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Event(P3,IncreasePoints(Trick,11))

Appraisal

Pride*

* Using a OCC Theory of Appraisal

Individual-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Event(P3,IncreasePoints(Trick,11))

How?

Group-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

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Appraisal

Pride

Individual-based Emotions

Assuming the robot is P1 and {P1, P3} ∈ T1

Event(P3,IncreasePoints(Trick,11))

Appraisal

Admiration *

* Using a OCC Theory of Appraisal

What are their Emotional Responses?

Using the verbal utterances!

Group-based Emotions

Individual-based Emotions

Ex: Partner increases the points

—”We are the best!” (Group Pride)

—“I am impressed with your move!” (Admiration)

What are their Emotional Responses?

Using the verbal utterances!

Group-based Emotions

Individual-based Emotions

Ex: Partner increases the points

—”We are the best!” (Group Pride)

—“I am impressed with your move!” (Admiration)

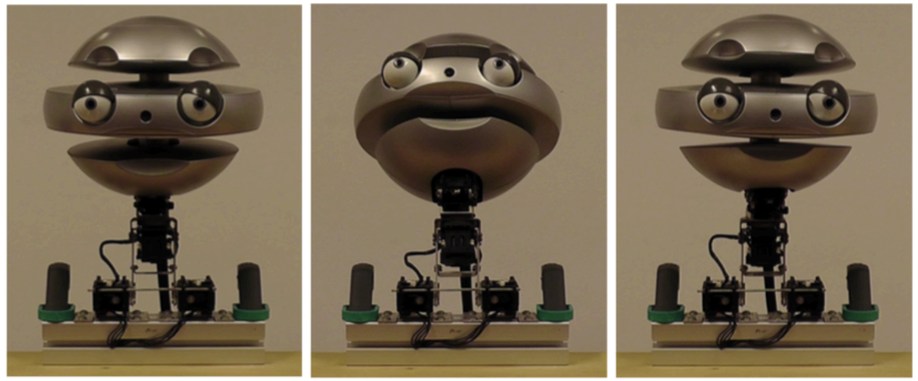
Ex: Robot decreased the points

—”Sorry partner, for this unfortunate move.” (Group Shame)

—“I am so ashamed of my move… ” (Individual Shame)

What are their Emotional Responses?

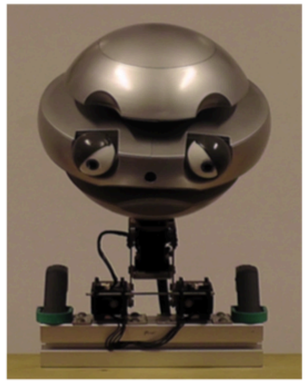
Using the physical posture!



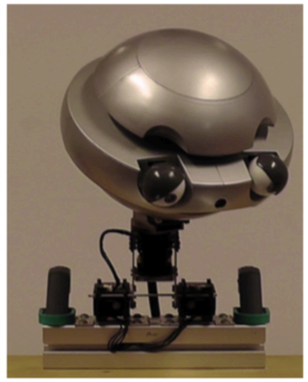
(a) Joy

(b) Pride

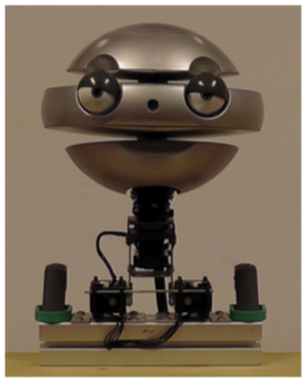
(c) Admiration



(d) Distress



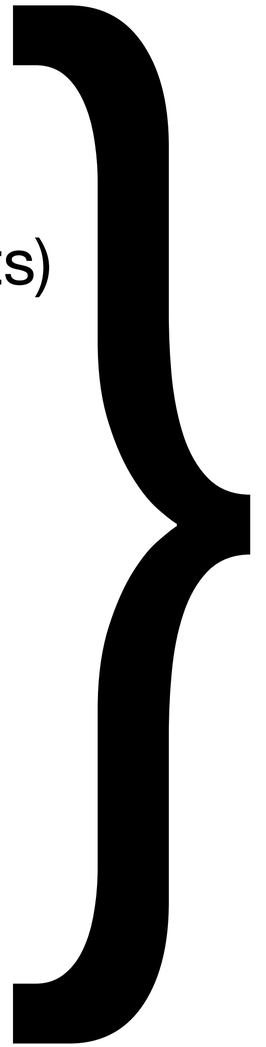
(e) Shame



(f) Reproach

Experimental Procedure

- Briefing and consent form
- Explain the rules and play an example game (without the robots)
- Random draw to assign the robotic partner
- 3 games with the robots
- Questionnaire
- Random draw of a cinema ticket
- Debriefing



Questionnaire Subjective Scales

Towards the robotic partner:

- [Leach et al., 2008] **Group Identification** (Satisfaction, Solidarity)
- [Bartneck et al., 2009] **Godspeed** (Anthropomorphism, Animacy, Likeability, Perceived Intelligence)
- [Allen et al., 2004] **Group Trust**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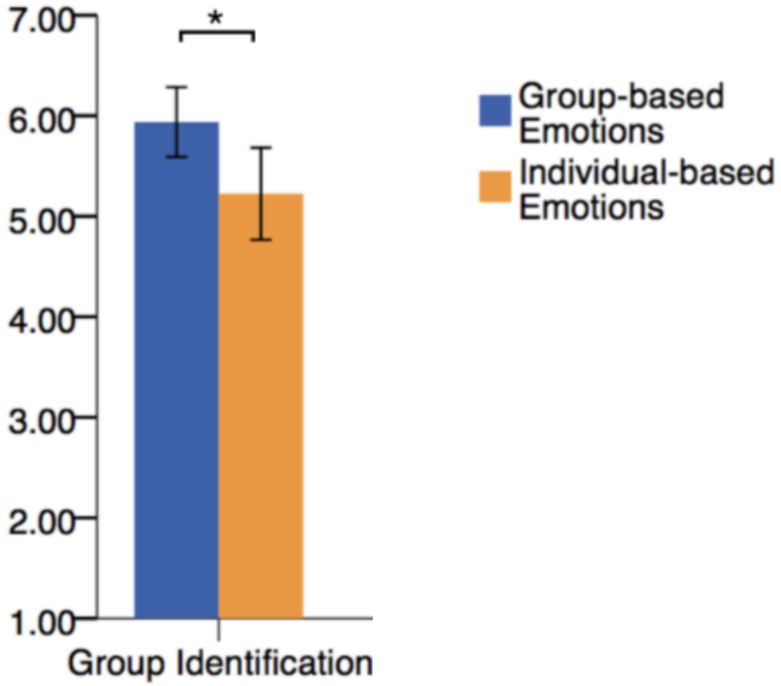
Sample

- 48 university students (24 sessions)
    - 33 males and 15 females
    - [19 - 33] years old (M = 25.02 ± 2.98)

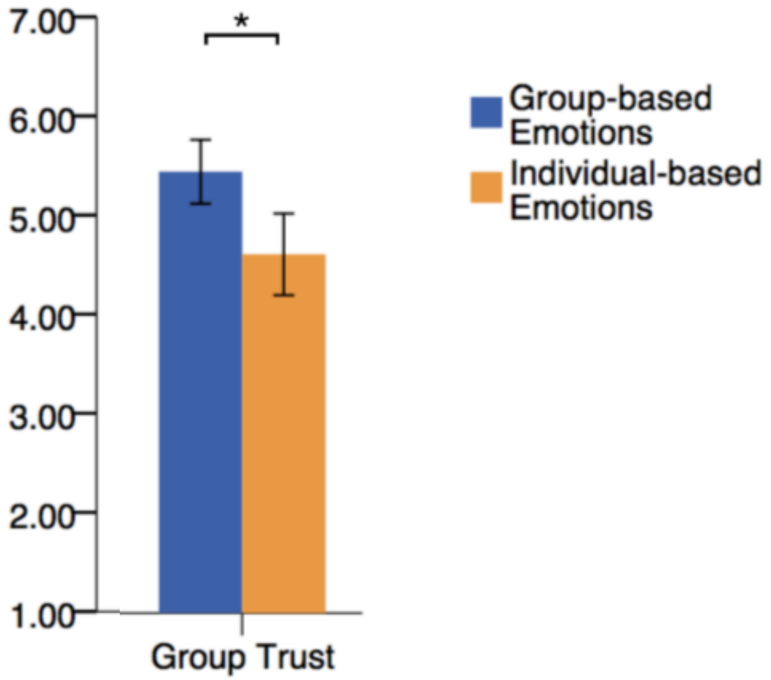
Results - Group Identification

- Participants had significantly higher levels (U = 175.5, p = 0.02, r = 0.335) of Group Identification towards the robotic partner with GbE than towards the robotic partner with IbE.



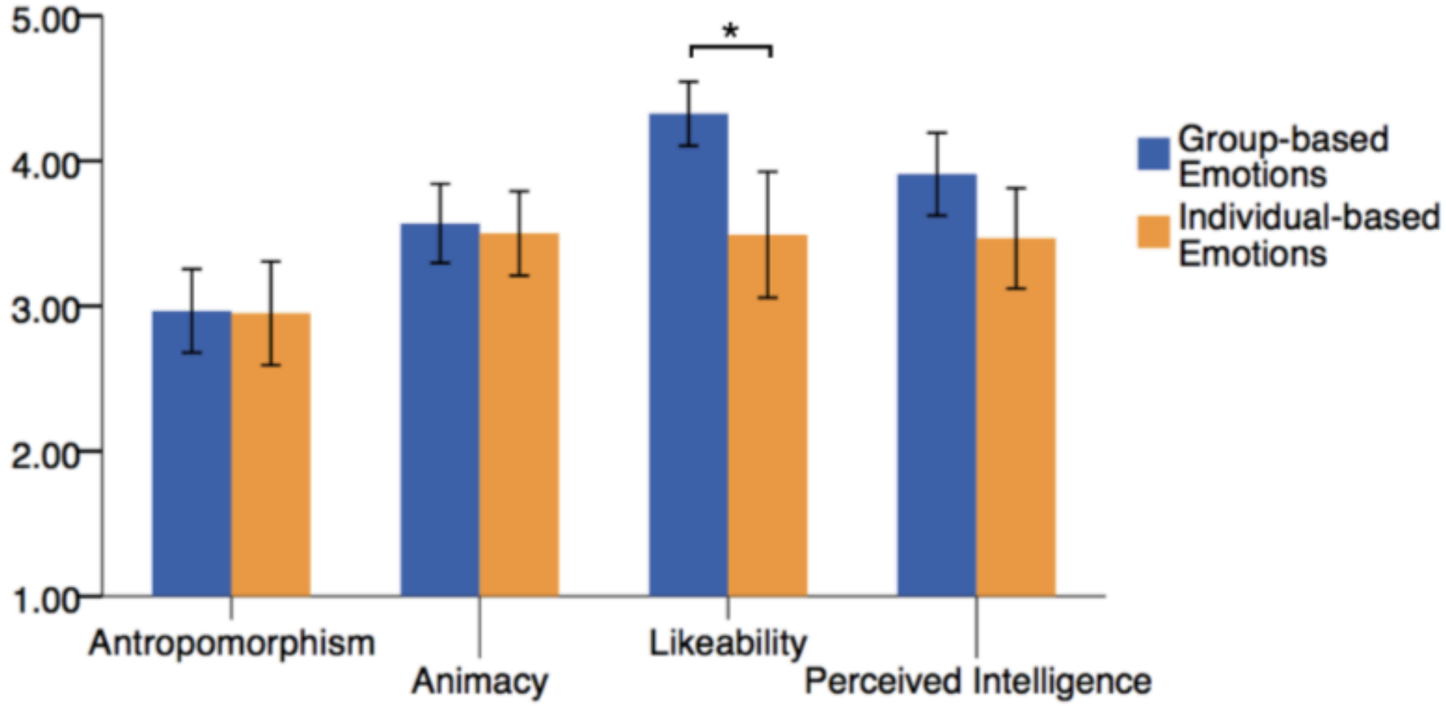
Results - Group Trust

- Participants had significantly higher levels ($U = 148$, $p < 0.01$, $r = 0.417$) of Group Trust towards the robotic partner with GbE than towards the robotic partner with IbE.



Results - Perception of the Robot

- Participants attributed significantly higher levels of **Likeability** to robotic partner with GbE than the robotic partner with IbE.



Discussion

- **H1**: Participants will have a stronger Group Identification with a robotic partner that expresses GbE.

- **H2**: Participants will have a more positive perception of a robotic partner that expresses GbE.

- **H3**: Participants will have a higher degree of Group Trust with a robotic partner that expresses GbE.

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I would love to hear your thoughts & questions now!

We may also get in touch later:

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