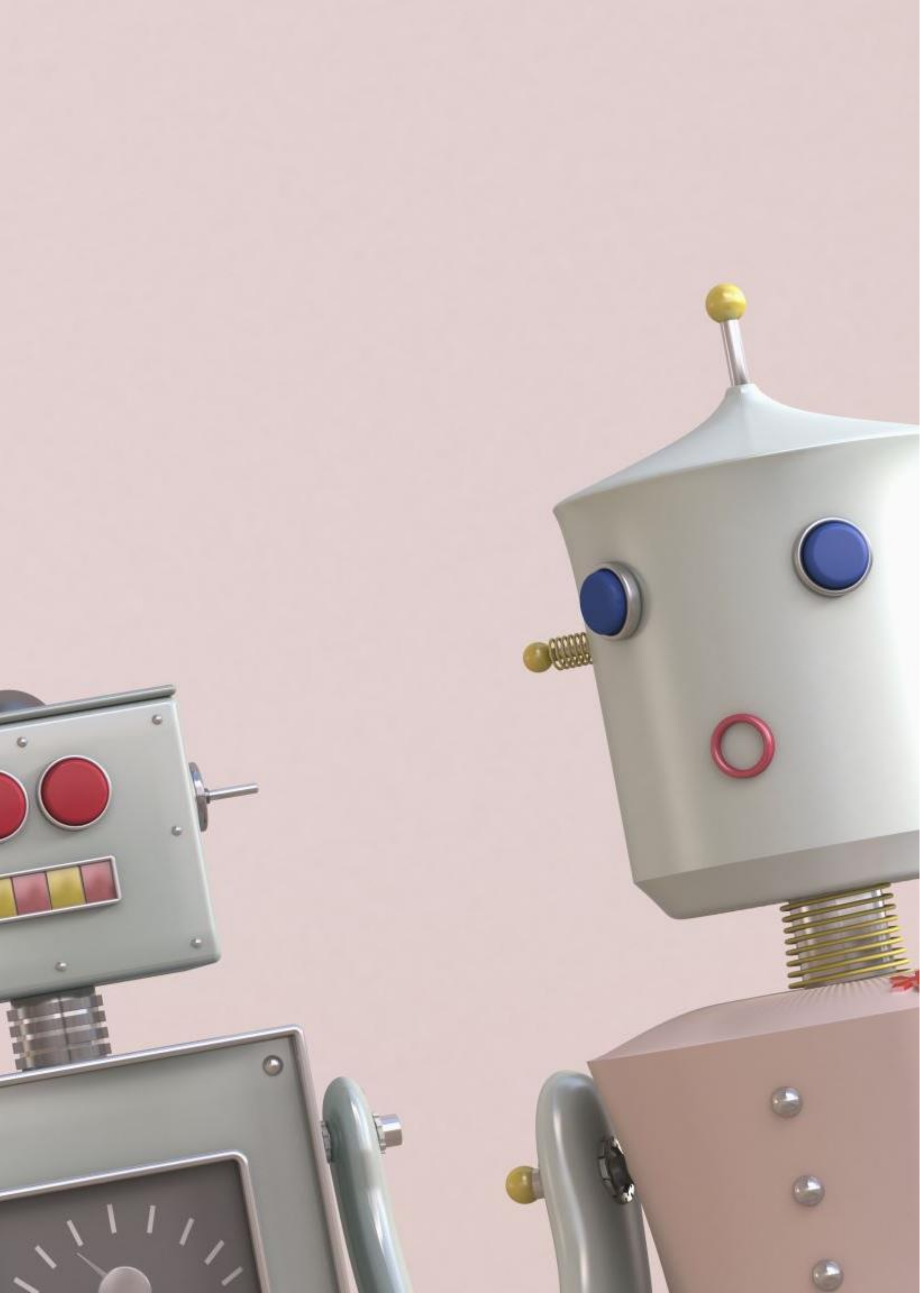


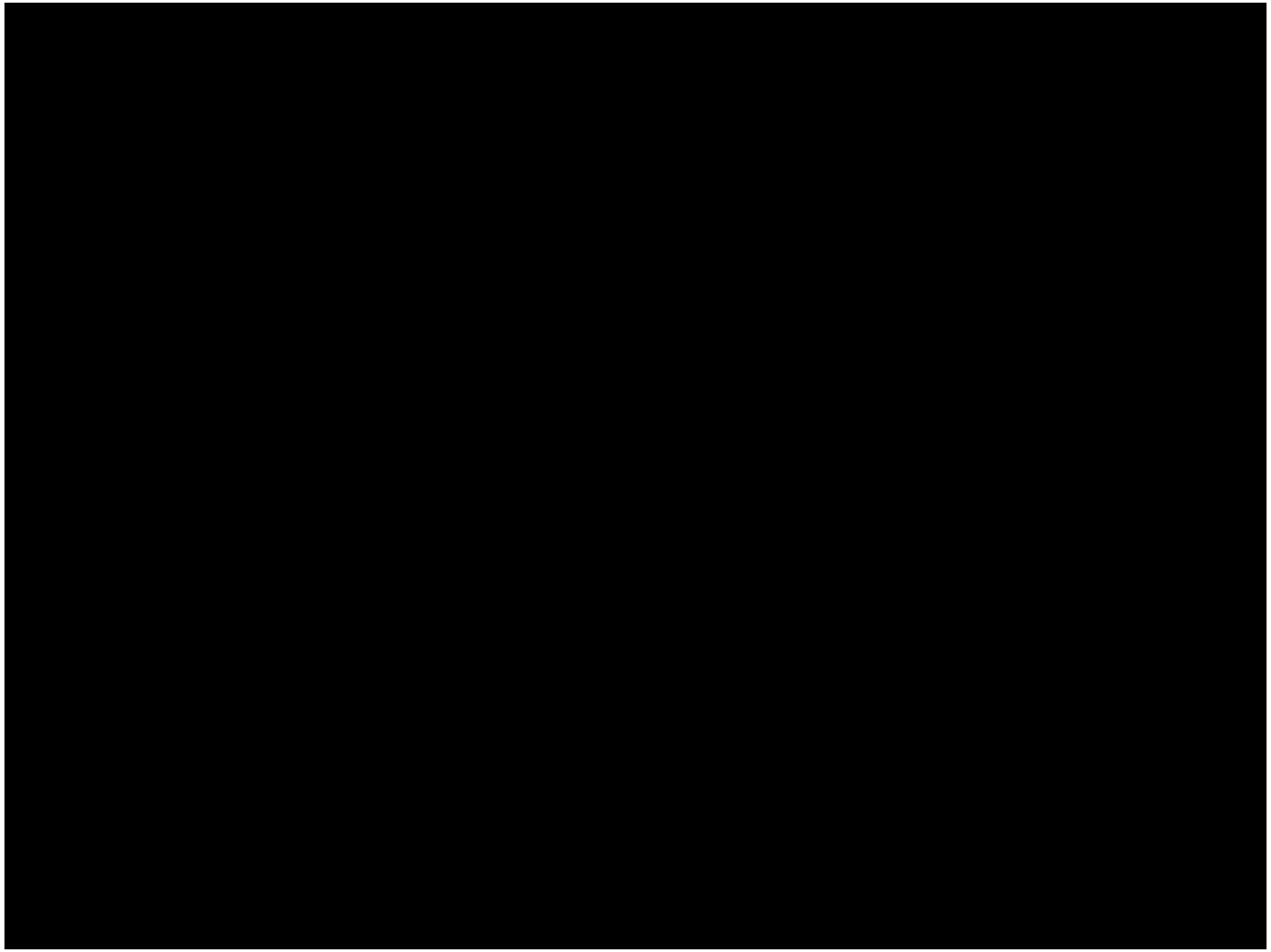
SOCIAL ROBOTS AND HUMAN-ROBOT INTERACTION

Emotions and Non-verbal behaviour in HRI

Ana Paiva

P2
2025/2026

Lets see a video



STUDYING EMOTIONAL RESPONSES TOWARDS ROBOTS: HYPOTHESES*

Can we feel emotions towards robots?

Hypotheses:

(H1a) People feel more negatively after the reception of the torture video compared to the normal video, and

(H1b) People show higher physiological arousal during the reception of the torture video compared to the nice video.

Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34.

STUDYING EMOTIONAL RESPONSES TOWARDS ROBOTS: HYPOTHESES*

Fig. 1 Example scenes from the friendly interaction: feeding, caressing, stroking

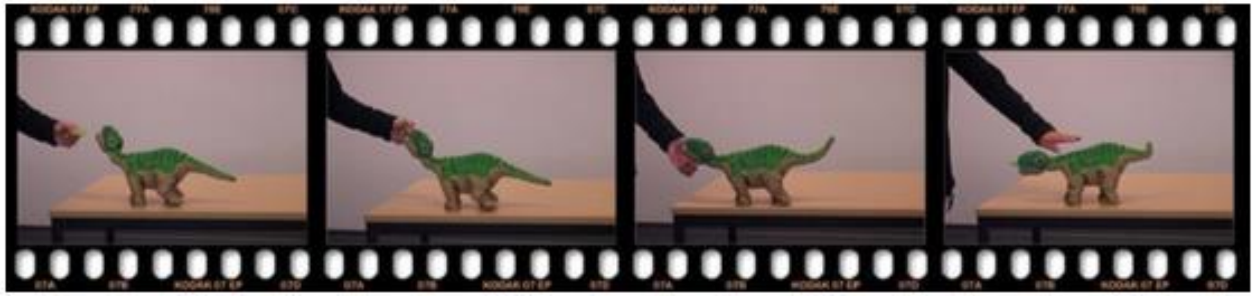


Fig. 2 Example scenes from the torturing interaction: punching, choking, hitting head on table, robot crouching down

**Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34.*

STUDYING EMOTIONAL RESPONSES TOWARDS ROBOTS: HYPOTHESES*

Experimental design:

2 × 2 design with

- one between-subjects factor "prior interaction with the robot" (prior interaction vs. no prior interaction) and
- - a within- subject factor "type of video" (reception of two different videos: friendly interaction video vs. torture video)

Table 1 Experimental design—distribution of participants over conditions ($N = 41$)

		Sequence of videos	
		Torture-friendly	Friendly-torture
Prior interaction with robot	With interaction	10	10
	Without interaction	10	11
Total N		20	21

*Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34.

STUDYING EMOTIONAL RESPONSES TOWARDS ROBOTS

Dependent Variables:

Physiological Arousal: measured with electrodermal activity. To measure, amplify and record the physiological signals, the V-AMP (http://www. brainproducts.com/) was used, which is a multi-modality physiological monitoring device that encodes biological signals in real time. Skin conductance responses (SCRs) were registered and Electrocardiogram (ECG) recorded.

Self-report Measures:

- ***PANAS***: the Positive and Negative Affect Schedule consisting of 20 items (e.g. strong, guilty, active, ashamed etc.), which were rated on a 5-point Likert scale from "very slightly or not at all" to "extremely".
- ***Evaluation of videos***: Nineteen self-constructed items were designed for the evaluation of the videos
- ***Evaluation of the Robot*** 16 items (e.g. stupid, warm, cold, confident, cheer- ful, weak), which were rated on a 7-point Likert scale from "strongly agree" to "strongly disagree".
- ***Empathy with the Robot*** This scale consisted of 12 self- constructed items, which were rated on a 5-point Likert scale from "strongly agree" to "strongly disagree". A factorial analysis of these items resulted in two factors.

**Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34.*

STUDYING EMOTIONAL RESPONSES TOWARDS ROBOTS

-Mixed-design ANOVAs with "prior interaction with the robot" as between-subjects variable and "type of video" as within-subject variable.

Empathy with robot yielded a significant main effect of **"type of video**" ($F\,(1; 39) = 139.539$; $p < .001$; $\eta 2 = .781$), that is:

Participants reported **"significantly more pity for the robot and anger towards the torturer after the torture video"** than they did after the normal video.

- Yet, there was no main effect of the second empathy factor or for "prior interaction with the robot", and nor were there any interaction effects.

**Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34.*

ATTRIBUTION OF FEELINGS TO THE ROBOT*

Table 10 ANOVA with the independent factors prior interaction with the robot and type of video and the dependent variable attribution of feelings to the robot ($N = 41$)

	TORT		NORM				
	μ	SD	μ	SD	F	η^2	p
Attribution of feelings to the robot	16.22	5.68	42.41	7.62	228.413	.854	<.001

Table 11 ANOVA with the independent factors interaction with the robot and type of video and the dependent variable evaluation of the videos – Factor Amusing Video ($N = 41$)

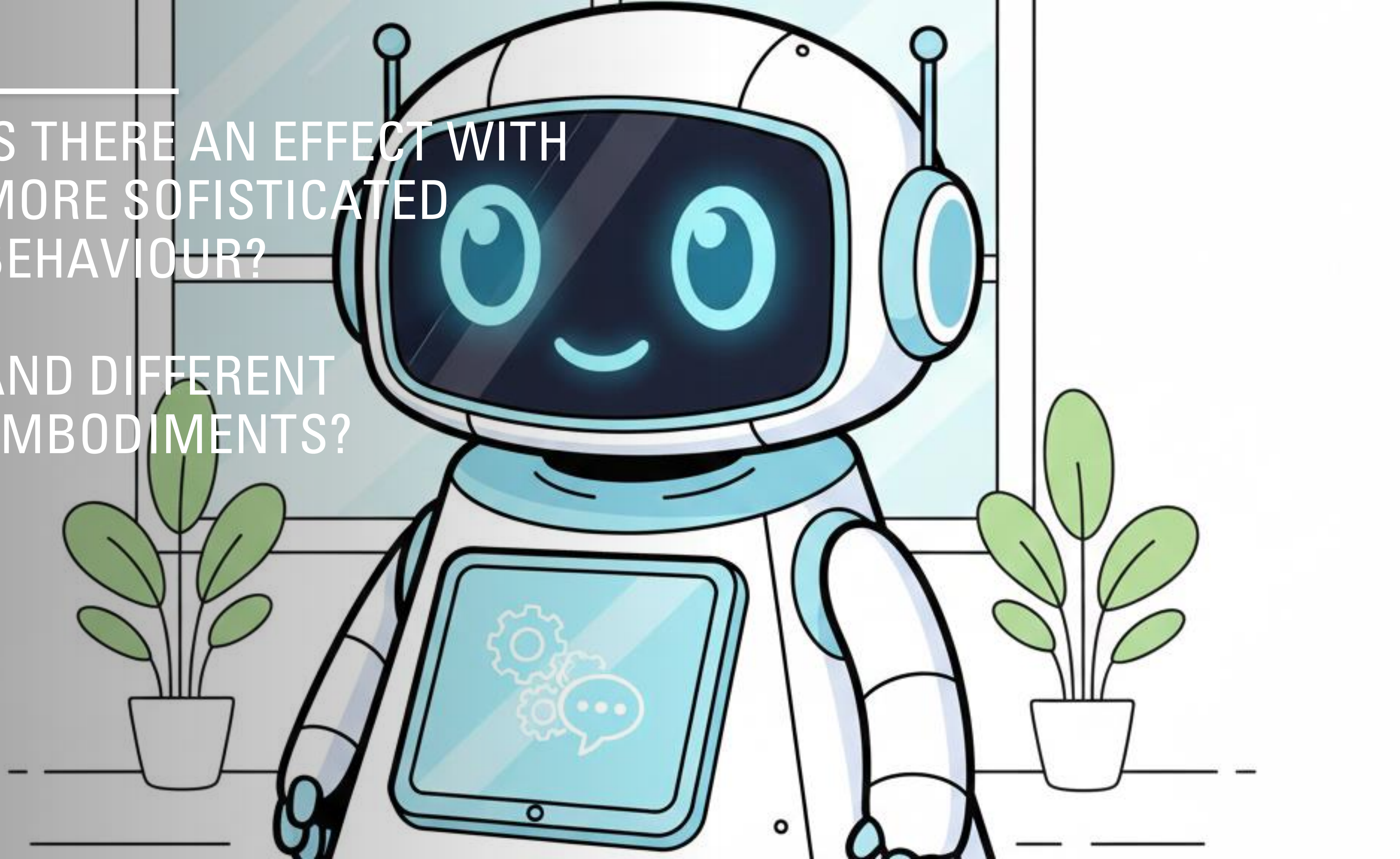
	TORT		NORM				
	μ	SD	μ	SD	F	η^2	p
With prior interaction	−.0429676	1.09	−.429691	1.09	4.475	.103	.041
Without prior interaction	.0451170	.93	.0451175	.93			

Participants attributed significantly fewer positive feelings to Pleo after the torture video than they did after the normal video

*Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34.

IS THERE AN EFFECT WITH MORE SOFISTICATED BEHAVIOUR?

AND DIFFERENT EMBODIMENTS?



TESTING EMOTIONAL RESPONSES TO A ROBOT (EMPATHY)

Scenario

1. First, the robot demonstrates its autonomous abilities and intelligence through interaction, (building rapport by engaging in friendly and casual conversation);

    (done while working on a distractor task (Sudoku) with the participant)

2. Once rapport established, the robot exhibits a "**functional**" problem, and reveals a "fear" of losing its memory if the problem were to be fixed.

3. This sets up a scenario where the participant can see that the robot has fear, and can potentially relate to the fear of losing one's memory.

4. Finally, the robot gets fixed and loses its memory, where hopefully the participant has an empathic response to the robot's fear happening: it lost its memory

**Seo, S. H., Geiskkovitch, D., Nakane, M., King, C., & Young, J. E. (2015, March). Poor Thing! Would You Feel Sorry for a Simulated Robot?: A comparison of empathy toward a physical and a simulated robot. In Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (pp. 125-132). ACM.*

SETTING OF STUDY: EMBODIMENT CONDITIONS

http://hci.cs.umanitoba.ca/permanent/hri/2015-nao-robotcontroller/.

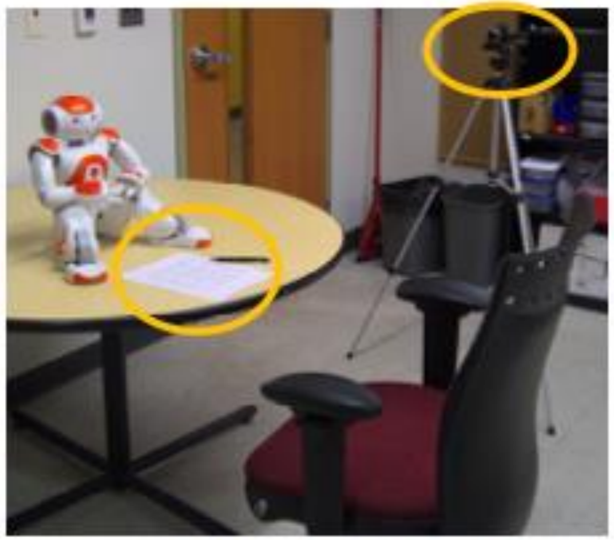


Figure 3. The study setup. A Sudoku board is placed between the participant and the robot. The interaction is recorded by a side camera, while a camera on the robot's head captures a live feed for the remote robot operator.

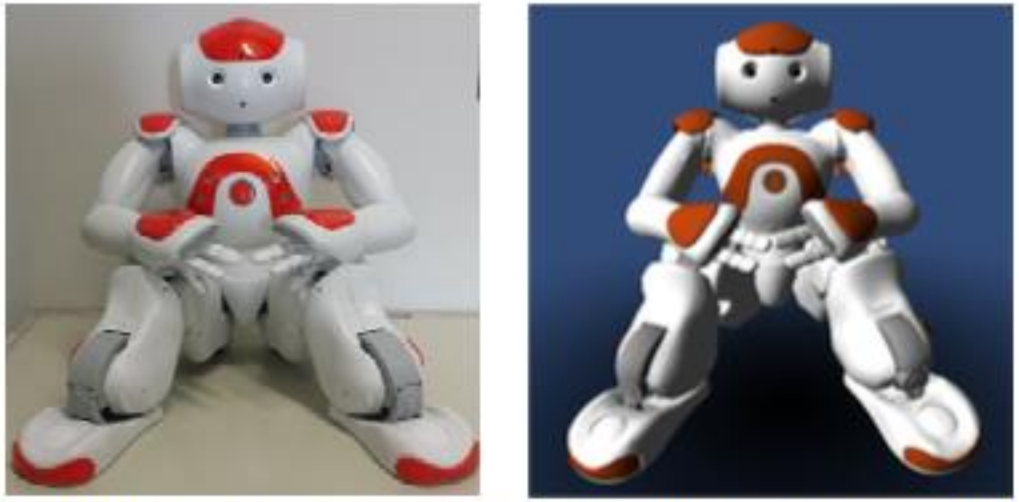
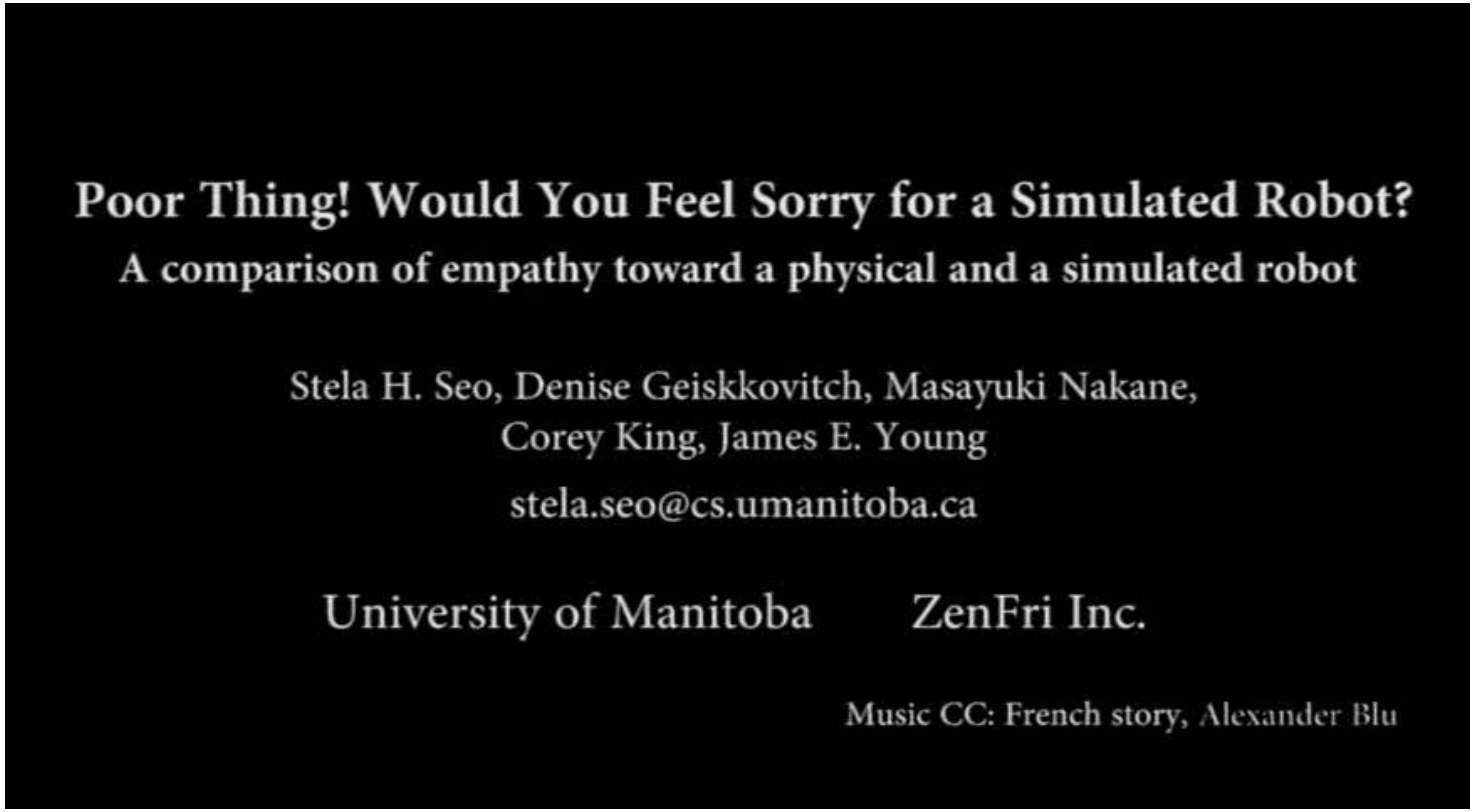


Figure 4. NAO, the humanoid robot used in our study. A simulated NAO (right) mimics movement of a real NAO.

3 conditions: physical robot, mixed-reality, and on-screen 3D simulated robot.

*Seo, S. H., Geiskkovitch, D., Nakane, M., King, C., & Young, J. E. (2015, March). Poor Thing! Would You Feel Sorry for a Simulated Robot?: A comparison of empathy toward a physical and a simulated robot. In Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (pp. 125-132). ACM.

CAN PEOPLE FEEL EMPATHY TOWARDS A ROBOT?

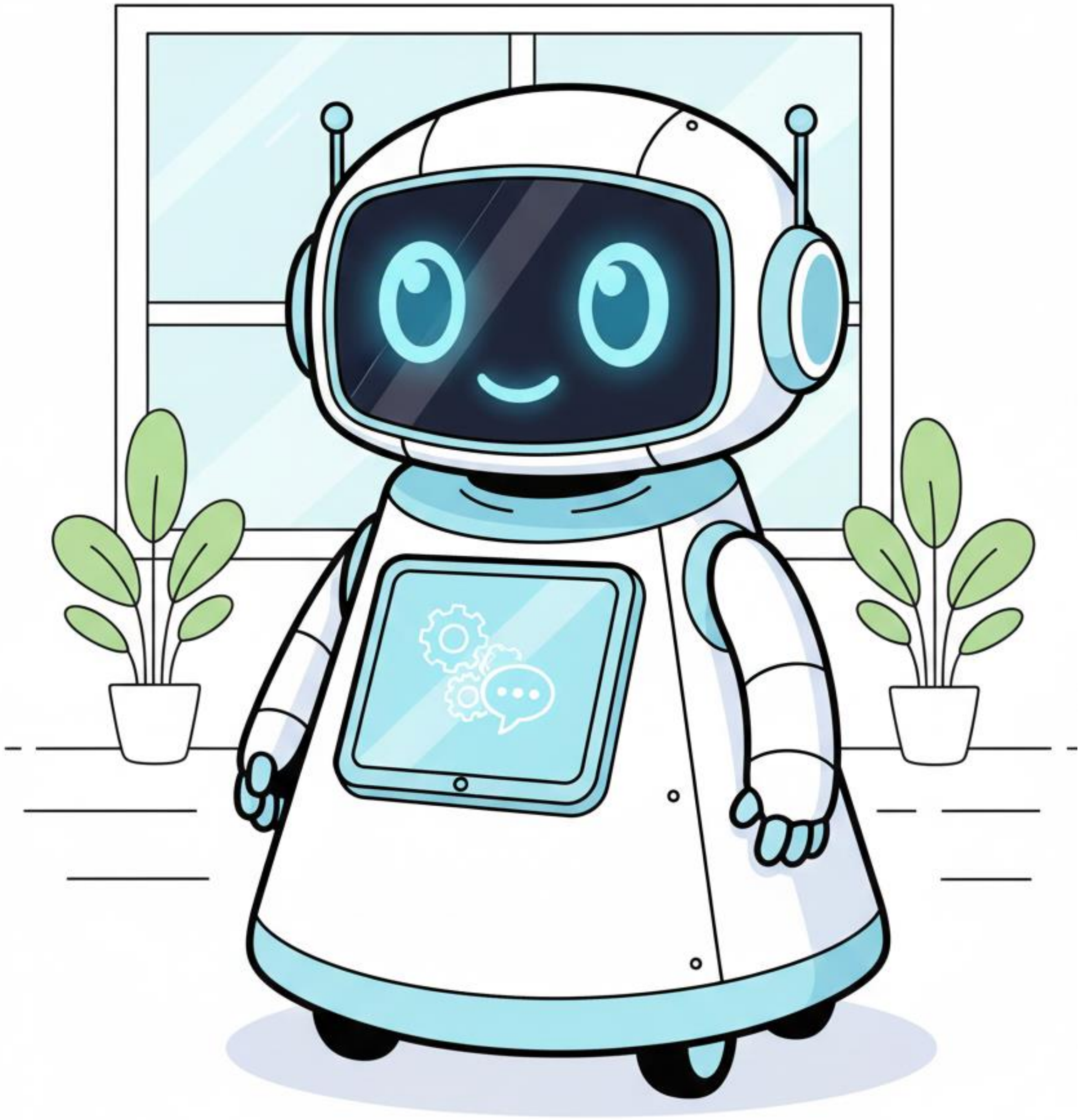


**Seo, S. H., Geiskkovitch, D., Nakane, M., King, C., & Young, J. E. (2015, March). Poor Thing! Would You Feel Sorry for a Simulated Robot?: A comparison of empathy toward a physical and a simulated robot. In Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (pp. 125-132). ACM.*

RESULTS

- Participants: 39 participants across conditions (20 male, 19 female, sex balanced across conditions) – 12 for physical robot, 13 for mixed-reality, and 14 people for on-screen 3D simulated robot.
- Results indicate a **primary effect of scenario on the level of empathy reported by participants** (between-participants ANOVA, $F_{2,36}=3.43$, $p<.05$).
- Participants reported **higher empathy with the physical robot**

**Seo, S. H., Geiskkovitch, D., Nakane, M., King, C., & Young, J. E. (2015, March). Poor Thing! Would You Feel Sorry for a Simulated Robot?: A comparison of empathy toward a physical and a simulated robot. In Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (pp. 125-132). ACM.*



LESSONS LEARNED

- People respond emotionally to robots (even in vídeos)
- Physical robots raise more emotional responses than virtual ones

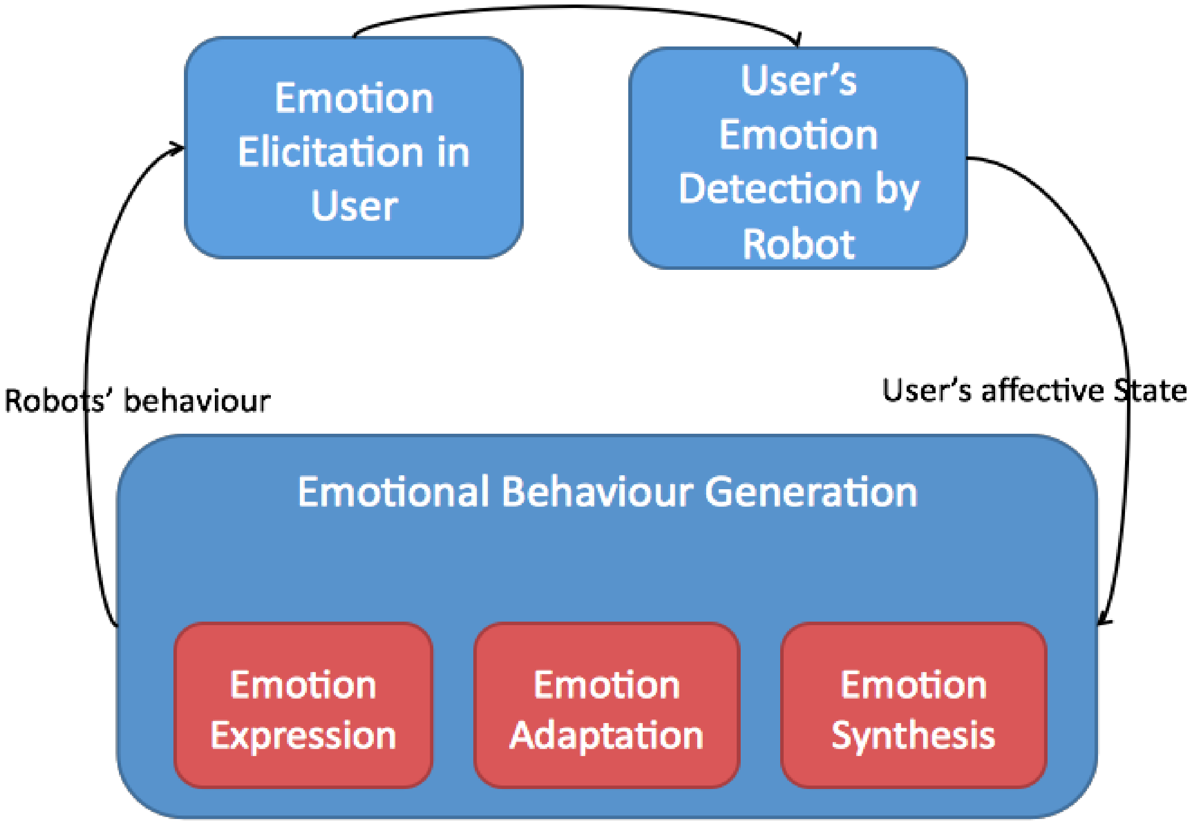
Question: and text based chatbots????

CREATING "EMOTIONAL" RESPONSES IN SOCIAL ROBOTS

Social robots that are able to exhibit emotion like responses to situations (thus generate "synthetic emotions" or express those "synthetic emotions")

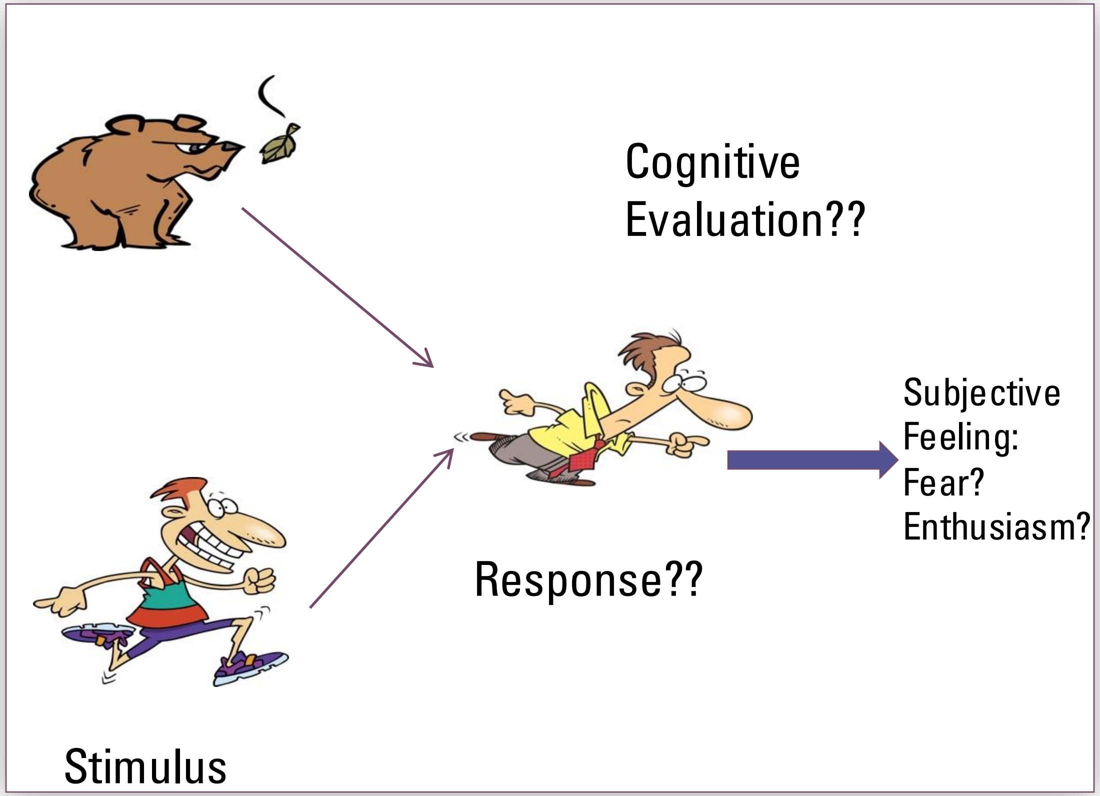
Why would we want that?

ROBOTS THAT EXHIBIT EMOTION LIKE BEHAVIOR



A BIT ABOUT EMOTIONS

- According to Descartes(1569-1650) there was a clear separation between the rational and the irrational.
- [Damasio] defends that reason and emotion cannot be seen as antagonic entities in our mind.



Appraisal models

CHARACTERISTICS OF EMOTION

"Structure & Function"

Structure: valence; arousal; dominance

Function:

- Facial feedback hypothesis (associated with specific feedback) (e.g. Ekman, Levenson, & Friesen, 1983)
- Action tendencies (Frijda, 1986)
- Emotion as a "motivator"

COMPUTATIONAL MODELS: HISTORICAL ANALYSIS

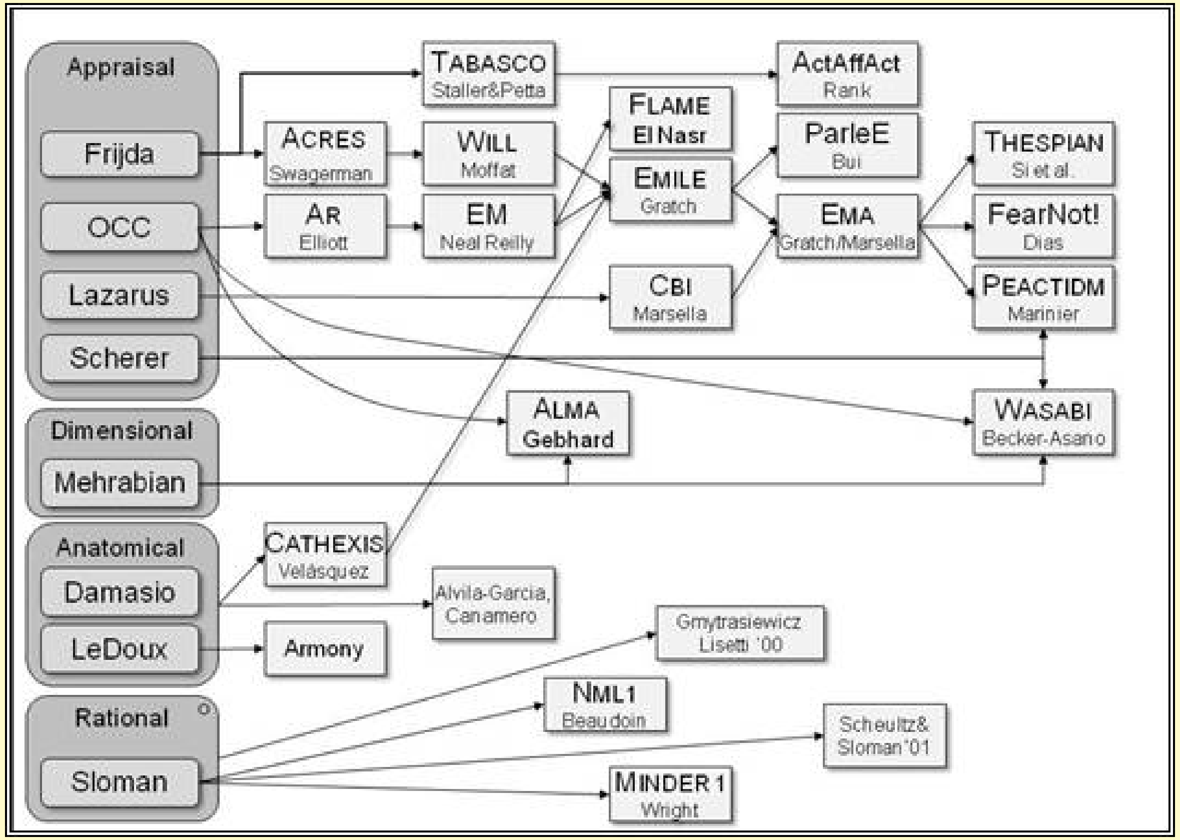


Figure 1Computational Models of Emotion (A history)

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EXPRESSING EMOTIONS IN ROBOTS

- Situations
- Perceptions
- Events

→ Appraisal →

Synthetic emotions

→ Reactions & Decision Making →

- Actions and Behavior
- What to say
- Gestures and Postures
- Other non-verbal behaviour

ICAT THE AFFECTIVE CHESS COMPANION

DESIGNING EMOTIONAL EXPRESSIVE RESPONSES

Design of a chess companion expressions: inspired on the characteristics of empathic tutors (Cooper et al., 1999)

- Non-verbal:
  - iCat's expressive behaviour **coherent to companion's inferred affective state** (role taking based on companion's state of the game)
  - Looks at the companion more (eg. 2 x more)
- Verbal:
  - Calls the companion by name (making it more personal)
  - Encouraging utterances ("don't worry, you had no better options", "I still believe you can win"…); versus impartial utterances for the opponent ("good move", "bad move"…)

ICAT OBSERVING 2 PLAYERS: EXPERIMENT

- Conditions
  - Empathic: companion
  - Neutral: opponent to the companion
- Procedure
  - Subjects played an entire game against each other
  - Filled in a friendship questionnaire + open questions

Dependent measure: Friendship

Use of the McGill Friendship Questionnaire (Mendelson, 1999)

Iolanda Leite, André Pereira, Samuel Mascarenhas, Carlos Martinho, Rui Prada, Ana Paiva: The influence of empathy in human-robot relations. Int. J. Hum.-Comput. Stud. 71(3): 250-260 (2013)

EXAMPLE:ICAT OBSERVING 2 PLAYERS...

opponent

companion

LIVING WITH ROBOTS
AND INTERACTIVE COMPANIONS

ICAT OBSERVING 2 PLAYERS: EXPERIMENT

- Sample
  - N = 40, 36 male and 4 female, 18-28 years
  - 20 in each condition (empathic, neutral)
- Procedure
  - Subjects played an entire game against each other
  - Filled in a friendship questionnaire + open questions

Dependent measure: Friendship

Use of the McGill Friendship Questionnaire (Mendelson, 1999)

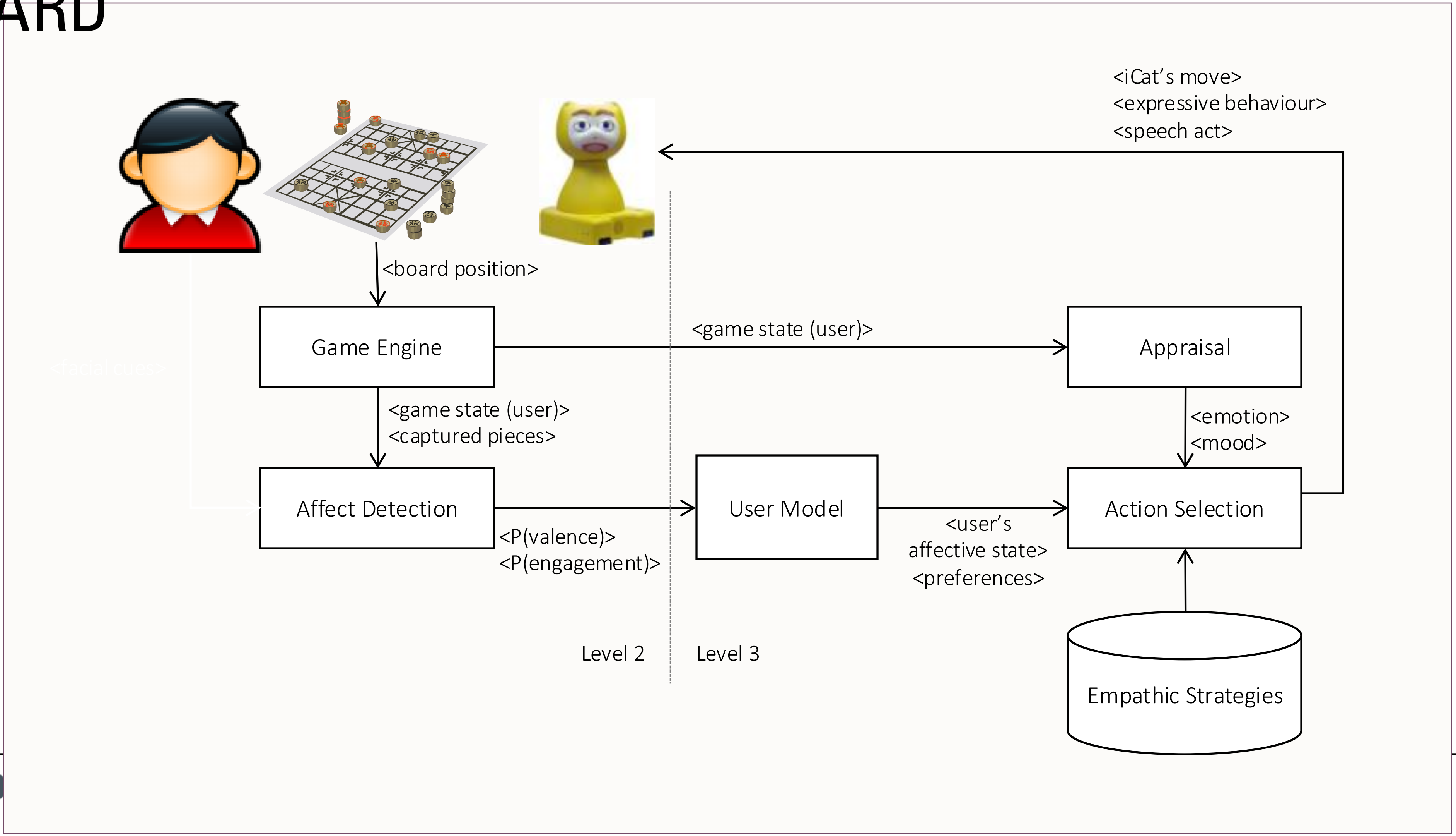
Results: Significant differences **between conditions for stimulating companionship** ($U = 72.5$, $p < 0.05$,
$z = -1.893$), reliable alliance ($U = 46$, $p < 0.01$, $z = -2.954$), **self-validation** ($U = 66.5$, $p < 0.05$, $z = -2.131$) and **intimacy***

Empathic condition: higher **stimulating companionship, self-validation and intimacy**

Iolanda Leite, André Pereira, Samuel Mascarenhas, Carlos Martinho, Rui Prada, Ana Paiva: The influence of empathy in human-robot relations. Int. J. Hum.-Comput. Stud. 71(3): 250-260 (2013)

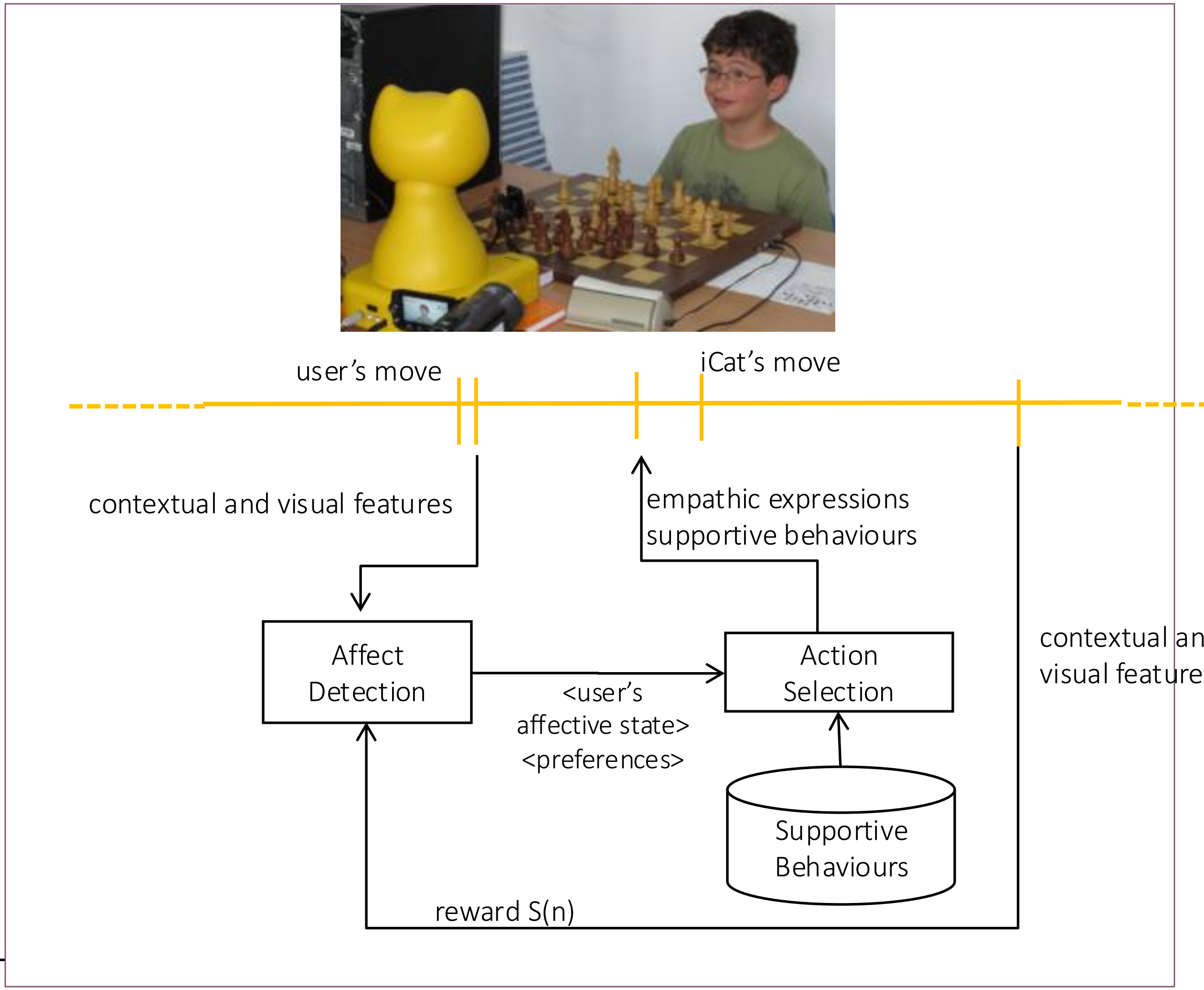
AND AS A GAME COMPANION?

ICAT USING THE USER’S EMOTIONAL RESPONSES AS A REWARD



ADAPTIVE EMPATHIC BEHAVIOUR

- Non-verbal behaviour
  - Mimic user's affective state
  - Suppress strong positive emotions
- Verbal behaviour
  - Speech acts to encourage and motivate the players (e.g., "you played very well this time")
- Game related
  - Allow user to take back move, explaining why
  - Suggest a good move
  - Play a bad move so that user can recover some disadvantage



AN EMPATHIC CHESS PLAYER

CLOSING THE AFFECTIVE LOOP USER STUDY

- Total of **84** participants, 8-10 years old
- **Individual** Interactions
  - 40 participants: 19 male, 21 female
- **Group** Interactions
  - 44 participants: 22 male, 21 female
  - 10 groups of 5 students (avg.)

Conditions

Neutral

Empathic: randomly selecting an empathic strategy

Adaptive_empathic: selecting strategy using RL algorithm

Condition	Individual	Group
0. neutral	13	
1. empathic	13	44
2. adaptive_empathic	14	
Total	**40**	**44**

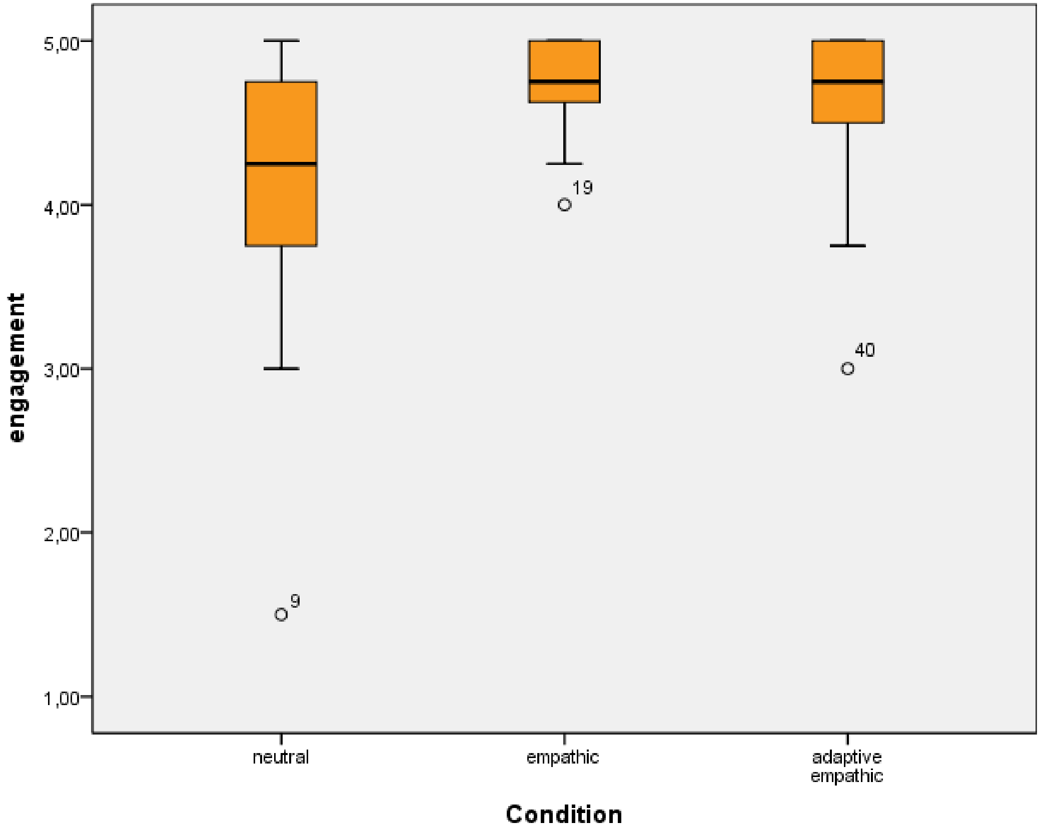
CLOSING THE AFFECTIVE LOOP WITH EMPATHY

Results

No significant differences between empathic conditions

- Long-term user study is needed to validate the model
- Time between employing the strategy and reward function should be different for some strategies

Engagement was higher in both empathic conditions



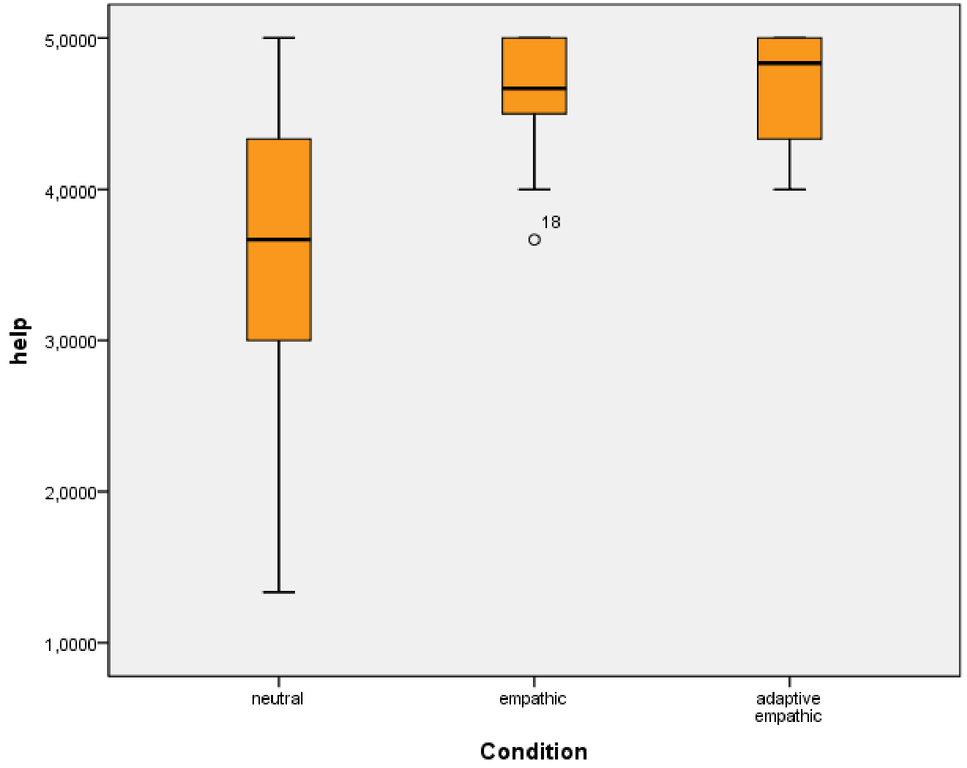
neutral vs. empathic:
U = 46
r = - 0.4
$p < 0.05$

neutral vs. adaptive_empathic:
U = 62
r = - 0.28
$p < 0.05$

Iolanda Leite, Ginevra Castellano, André Pereira, Carlos Martinho, Ana Paiva: Modelli empathic behaviour in a robotic game companion for children: an ethnographic study world settings. HRI 2012.

CLOSING THE AFFECTIVE LOOP USER STUDY

Subjects in the empathic conditions found the robot more helpful: $H(2) = 10.53$, $p < 0.05$



neutral vs. empathic:
$U = 33$
$r = -0.53$
$p < 0.05$

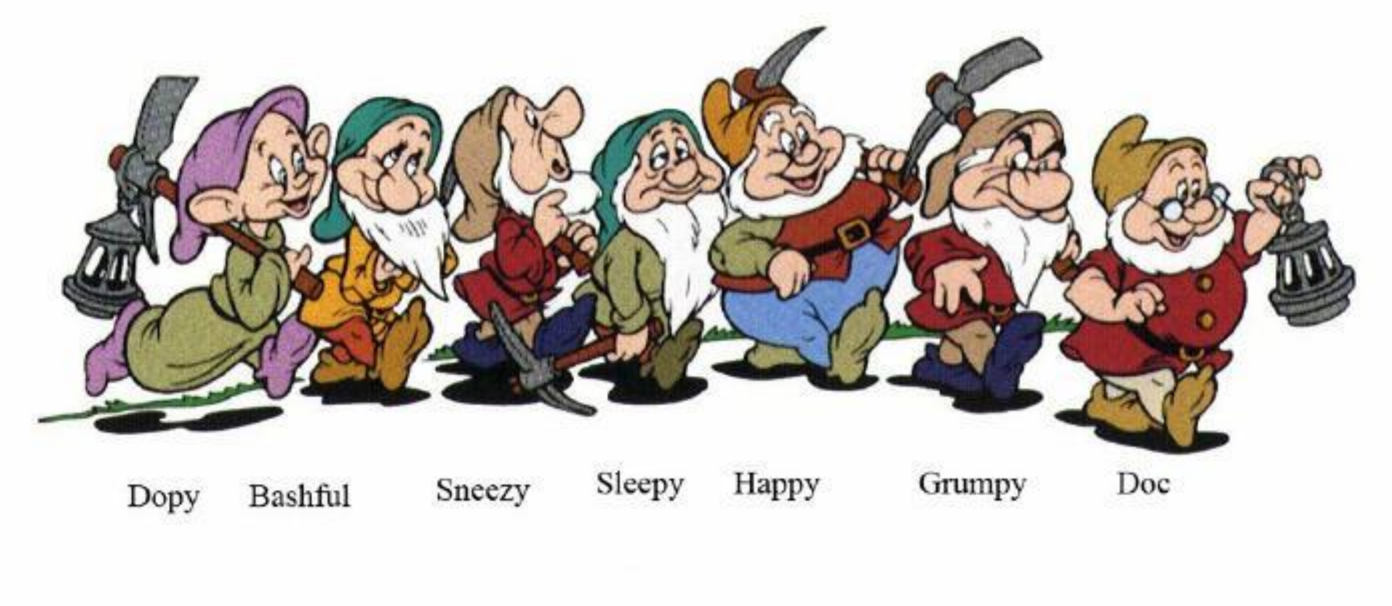
neutral vs. adaptive_empathic:
$U = 34$
$r = -0.56$
$p < 0.05$

EXPRESSING EMOTIONS IN MOVEMENT

Can we show emotion in non anthropomorphic robots?

CASE: GIVING PERSONALITY TO A DRONE

Inspiration



The seven dwarfs represent key personalities that are well known across cultures.

Cauchard, J. R., Zhai, K. Y., Spadafora, M., & Landay, J. A. (2016, March). Emotion encoding in human-drone interaction. In 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 263-270). IEEE.

Designing different personalities

Cauchard, J. R., Zhai, K. Y., Spadafora, M., & Landay, J. A. (2016, March). Emotion encoding in human-drone interaction. In 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 263-270). IEEE.

TABLE I. CHARACTERISTICS OF STEREOTYPES OF PERSONALITY AND MATCHING EMOTIONS

Personality (Emotional State)	Characteristics
The Big Boss (Brave)	• Confident and Disciplined • Looks directly at a person • Never goes backwards; instead, turns around and moves forward • Directly executes commands, although it may take charge and do the task its own way • Moves quickly and smoothly
The Goofy Comedian (Dopey / Sleepy)	• Delayed reaction time to commands (Misunderstands / Slow to react) • Moves sloppily / Wobbles (rotating) • Uneven rhythm / Slow (starts and stops as it gets distracted or needs to rest) • Gets distracted, bumps into things, unpredictable
The Detached Philosopher (Grumpy)	• Reserved, uncooperative, impulsive • Have to repeat commands (begrudging) • Keeps its distance • Drags along
The Lovable Romantic (Happy)	• Trusting, affectionate, comfortable close to the user • Disciplined but imaginative (follows commands its own way, may not take the most direct path) • Moves and reacts quickly • Constant speed but unpredictable path
The Peaceful Artist (Sad)	• Self-pitying, keeps its distance • Non-responsive (slow, dragging) • Gentle and small movements • Flies low to the ground
The Sneaky Spy (Scared)	• Anxious, insecure, suspicious, reserved • Nervous, looks around for danger (jerky movements and stops to look around) • Scared when called • Keeps its distance, stays low
The Model Student (Shy)	• Anxious, insecure • Gradually builds trust (starts slow with some delay, that changes over time) • Takes coaxing for commands

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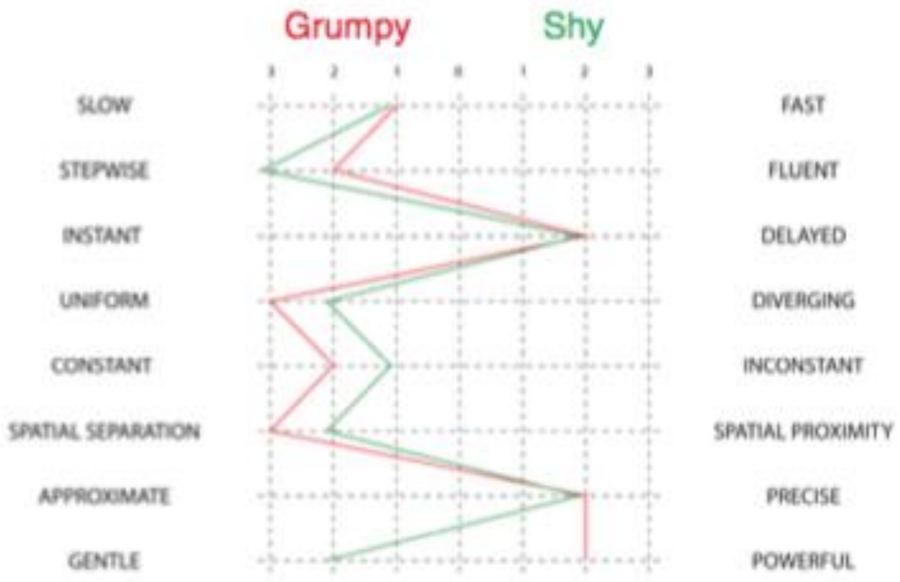
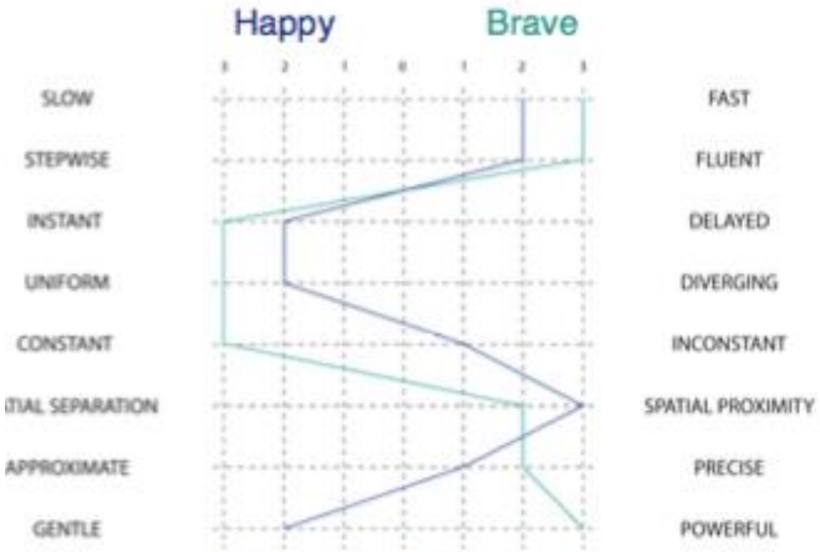
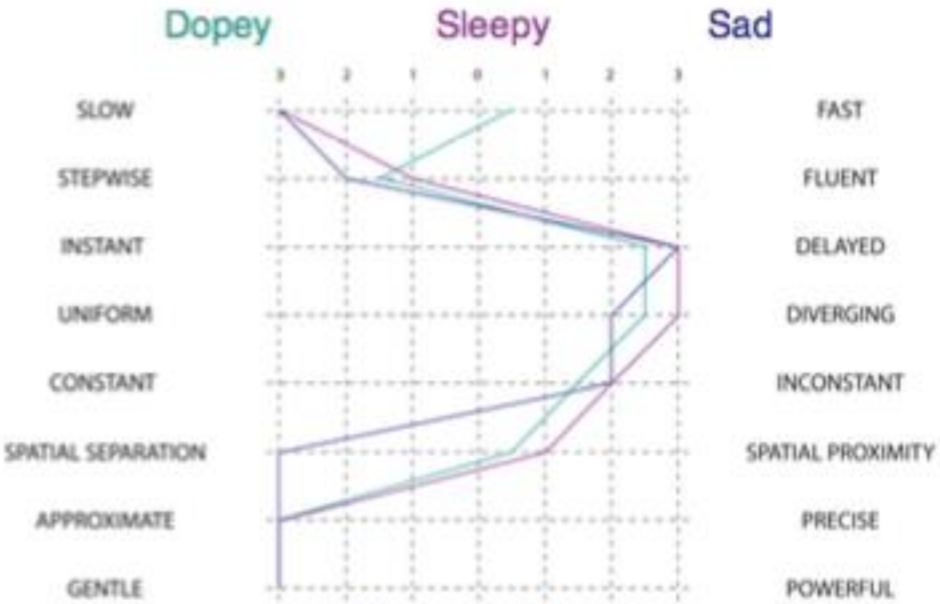


Anti-Social Drone



Adventurer Hero Drone



Exhausted Drone

DEFINING THE MOVEMENTS AND ANALYSIS USING *INTERACTION VOCABULARY*

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DEFINING THE STEREOTYPES

After the analysis:

- Dopey, Sleepy, and Sad, together become the *Exhauste* Drone.
- Grumpy and Shy were merged as the *Anti-Social* Drone, and
- Happy and Brave joined together as the *Adventurer Her* Drone.
- Three different stereotypes of personality models that constitute the Emotional Model Space for drones:

    The Exhausted Drone
    The Anti-Social Drone
    The Adventurer Hero Drone

TABLE II. CONTROL PARAMETERS FOR THE 3 PERSONALITY MODELS.

Personality Profile	Control Parameters			
	Speed (mph)	*Reaction Time (sec)*	*Altitude*	*Special Movements*
Adventurer Hero	7.7	Instant	High	Spins / Flips
Anti-Social	4.4	Delay (2s)	Middle	Starts and Stops
Exhausted	1.1	Delay (3s)	Low	Wobbles

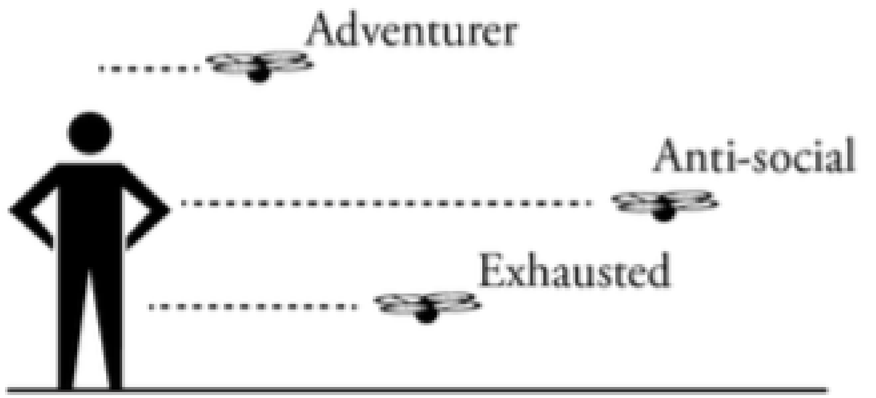


Fig. 4. Drone's altitude compared to the user for each personality model.

VIDEO

USER STUDY

A within-subjects user study with 20 volunteers from 18 to 39 years old (10 female / 10 male) across the three personality models.

Tasks: participant's role was to observe the drone's movements and reactions to a set of commands and interpret them as an emotional state

TABLE III. Drone Tasks and How They Differ Based on the Personality Models.

Tasks		Differences between personality models
Navigation	Stop	• Loitering animation sequence • Distance and height compared to participant
	Precise Location	• How direct the path is • How quickly the drone reaches its target
General Motion	Stop (after flying)	• How quickly the drone obeys the command after hearing it
Relative to User	Get Attention	• How quickly the drone acknowledges the participant and where it "looks"
	Take a Selfie	• How the drone confirms that a picture was taken

Cauchard, J. R., Zhai, K. Y., Spadafora, M., & Landay, J. A. (2016, March). Emotion encoding in human-drone interaction. In 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 263-270). IEEE.

RESULTS

TABLE V. AVERAGE RECOGNITION RATES OF PERSONALITY MODELS USING BOTH PRIMARY AND SECONDARY KEYWORDS.

Condition	Exhausted *(Dopey, Sad, Sleepy)*	Anti-Social *(Grumpy, Shy)*	Adventurer *(Happy, Brave)*
Primary keyword	45	45	**90**
Primary + Secondary keyword	**80**	**75**	**100**

- Exhausted Drone

P1	*"It kind of wobbled in the air and dropped – tired"*
P3	*"Sharp movements but not always very coordinated, seems incompliant but bold"*
P4	*"It usually messed up the first time or was extremely wobbly when flying"*
P7	*"Could also be a drunk drone, seemed to like to rest a lot by landing"*
P8	*"Shakey and stayed low"*
P16	*"Slow to respond, disobedient, could be because it's mad or stupid"*
P18	*"Since commands didn't really require multiple promptings, I figured it was faithful and obedient, so when it kept dropping and acting drunk, I immediately assumed sleepy"*

- Anti-Social Drone

P1	*"There was a part where the drone spun around, which was maybe angry or just refusing to do something."*
P4	*"More "obedient""*
P5	*"The drone was resistant to commands so it made me feel as though the drone was displaying aggression to the driver"*
P9	*"The drone didn't seem to "get it". Just kind of moped around"*
P11	*"stops after some meters and goes on...not frontal facing"*
P16	*"Quick to move away, slow to come back"*
P18	*"At first I was thinking sad/low energy because it took multiple commands every time and it kept flying*

- Adventurer Hero Drone

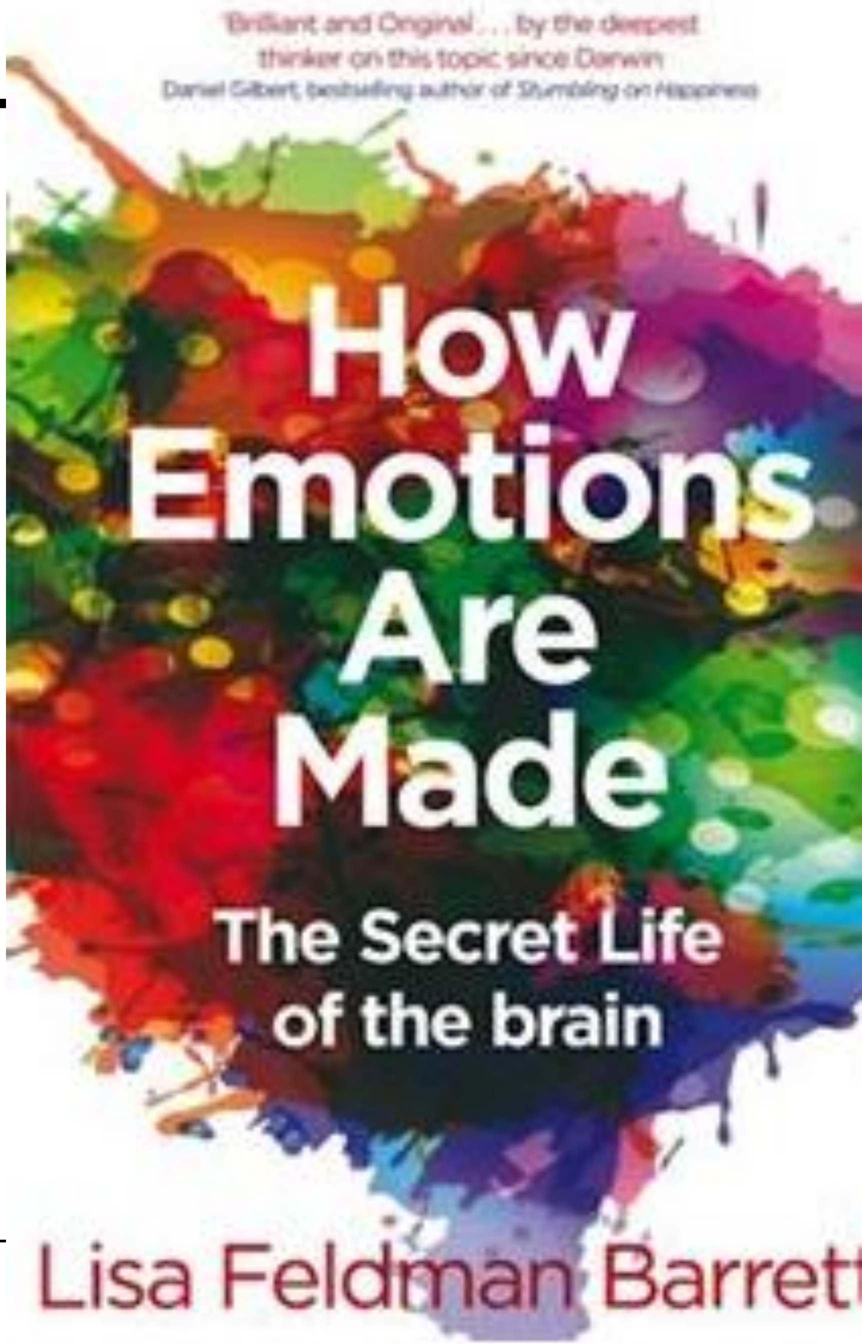
P1	*"Faster responses = brave/happy"*
P2	*"mostly thought it was happy because it twirled a lot"*
P3	*"The drone danced and did flips, usual indicators of happiness. It was fun and exciting to watch."*
P4	*"More distinct actions - flipping, responsiveness"*
P5	*"It flew a lot with its nose down so it seemed to me to signal bravery"*
P7	*"Extra movements made it look like the drone couldn't contain its excitement"*
P8	*"Moving quickly and all around, doing flips ("fun" things)"*
P9	*"It seemed really excited!"*
P13	*"Seemed very excited"*
P16	*"responded to command quickly, moved quickly, extraneous flips give the happy impression"*
P19	*"Excess movement/ornamentation, comparable to an excited dog"*

CRITICISMS

Oversimplification of Emotion: Lisa Feldman Barrett (and others) argue that there is a potentially flawed foundation (universal, discrete emotions).

Decontextualization: Emotions and emotional expressions are context dependent and is crucial for true emotional expression and understanding.

Ethical concerns: machines are not human, and emotional expressions may lead to emotional dependence (recent court cases against OpenAI), deception, manipulation, and problems of privacy.



BEYOND EMOTIONAL EXPRESSIVE BEHAVIOUR: OTHER NON-VERBAL BEHAVIOUR

NON-VERBAL COMMUNICATION AS MECHANISMS FOR MANAGING CONVERSATIONS

There are different mechanisms for managing conversations:

- (Who) Role-Signaling Mechanisms. Interlocutors of a conversation engage in discourse at varying levels of involvement: their "participant roles" or "footing", or "participant structure" of the conversation;

- (When) Turn-Taking Mechanisms. Role shifts among conversational participants by a turn-taking mechanism, which allows interlocutors to seamlessly exchange speaking turns, interrupt, etc;

- (What and How) Topic-Signaling Mechanisms. Participants in a conversation create a discourse, that is a composition of discourse segments in particular structures [Grosz and Sidner 1986]. Such structures signal shifts in topic in the discourse or how information is organized. Also, speakers produce a "number of cues" that signal these structures and enable contributions from other participants or to direct attention to important information (these signals include nor only verbal cues but also nonverbal cues, in particular gaze and gestures).

LET'S FOCUS ON NON-VERBAL COMMUNICATION...

With robots, given their *physical embodiment*, we can add to the verbal communication some level of *non-verbal communication*.

Head nods

Gaze
Handshake

GAZE

Gaze: During interaction people look at each other in the eye, while listening, talking…..

Without eye contact people do not feel they are in communication!

Gaze provides a number of potential social cues that can be used by people to learn about the social context, about the environment (objects and events) or even about internal (emotional and intentional) states of others.

- Gaze cues serve a number of functions in conversations.

GAZE AND EMBODIMENT

Gaze cues can be used in social robots also to serve as functions in conversations:

- Clarify who is addressed
- Help the speaker hold the floor (turn-taking);
- Help in signaling change in topics of conversation.

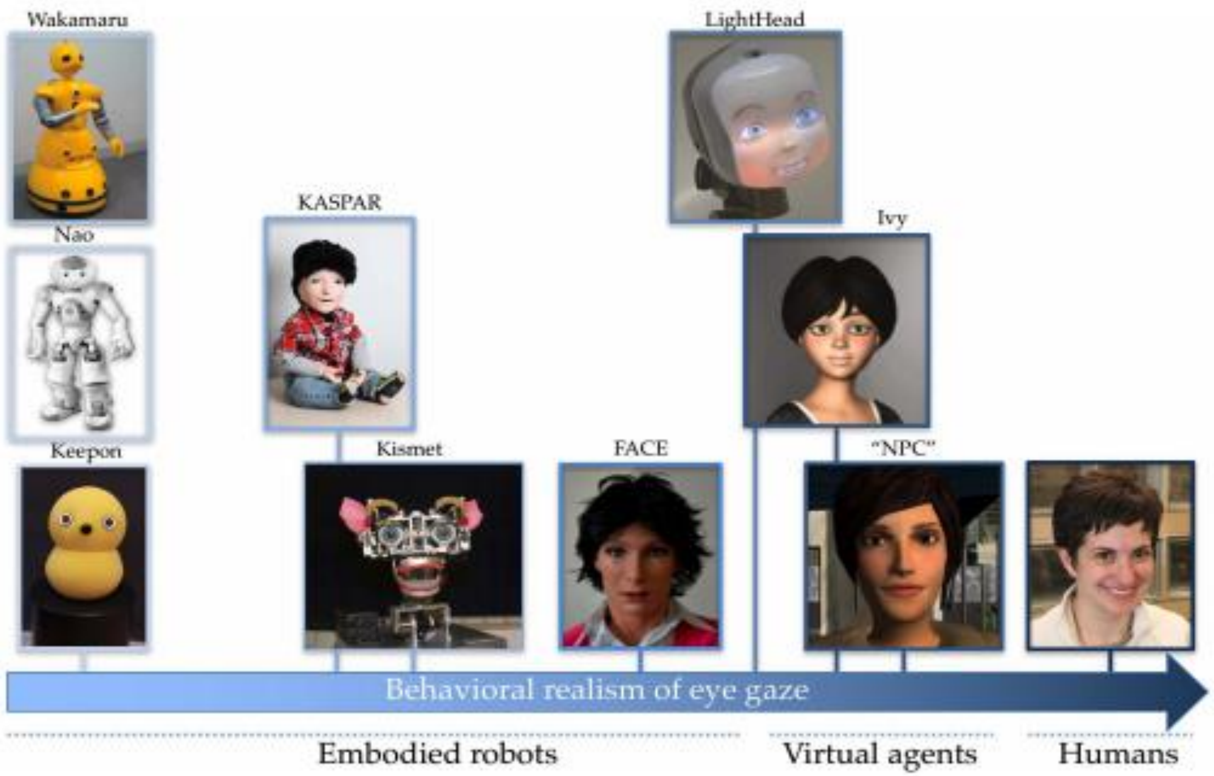
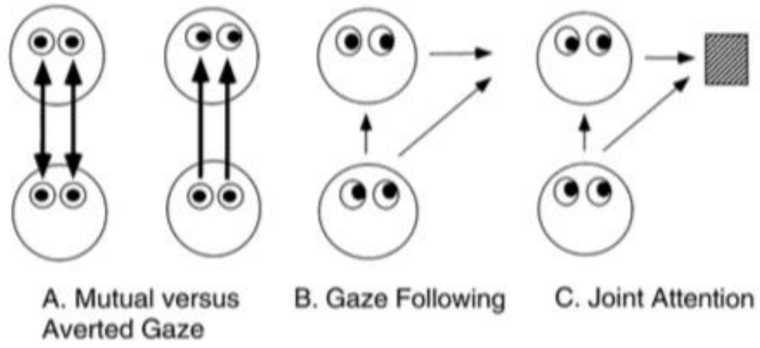
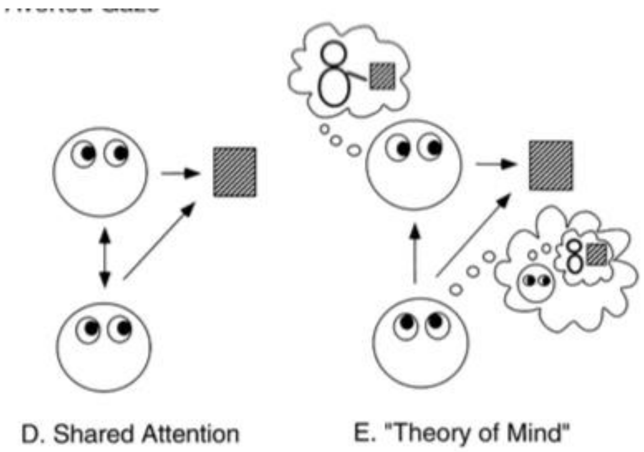


Figure 1. Robots and virtual agents with a range of appearances and capabilities are used for gaze research in HRI. This spectrum roughly sketches the range of behavioral realism with examples drawn from research cited in this review: Wakamaru (Szafir & Mutlu, 2012), Nao (Aldebaran, 2015), Keepon (author photograph), KASPAR (courtesy of the Adaptive Systems Research Group, University of Hertfordshire, UK), Kismet (Breazeal & Scassellati, 1999a), FACE (Zaraki, Mazzei,

TYPES OF GAZE: DIRECTION





- **Mutual gaze** is where the attention of two individuals is directed to one another;
- **Gaze following** is where individual A detects that B's gaze is not directed towards them, and follows the line of sight of B onto a point in space;
- **Joint Attention** is similar to Gaze Following except that there is a focus of attention, for example an object, that two individuals A and B are looking at, at the same time.

- **Shared Attention** is a combination of mutual attention and joint attention, so the focus of one both individuals A and B's attention is not only on the object but also on each other (example: I know you're looking at X, and you know that I'm looking at X)
- **Theory of mind**, uses a combination of the previous attentional processes, and higher-order cognitive strategies allowing to reason about the other’s attention

BUILDING GAZE BEHAVIOURS IN ROBOTS

Theory driven: (based on theories of human communication and the role of gaze, models can be built to replicate certain functions identified; e.g. use of the Politeness Theory by Brown and Levinson 1987);

Data driven (based on experiments and data collected with the precise scenarios in which we will build the robot's gaze behaviour)

Hybrid Approaches

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EXAMPLE: MODELING CONVERSATIONAL GAZE MECHANISMS

Hybrid approach: Build a model for Gaze behaviour based on both theory and data.

Initial data collection:

- to capture the basic spatial and temporal parameters of gaze cues
- to capture aspects of conversational mechanisms that signal information, conversation, and participation structures.

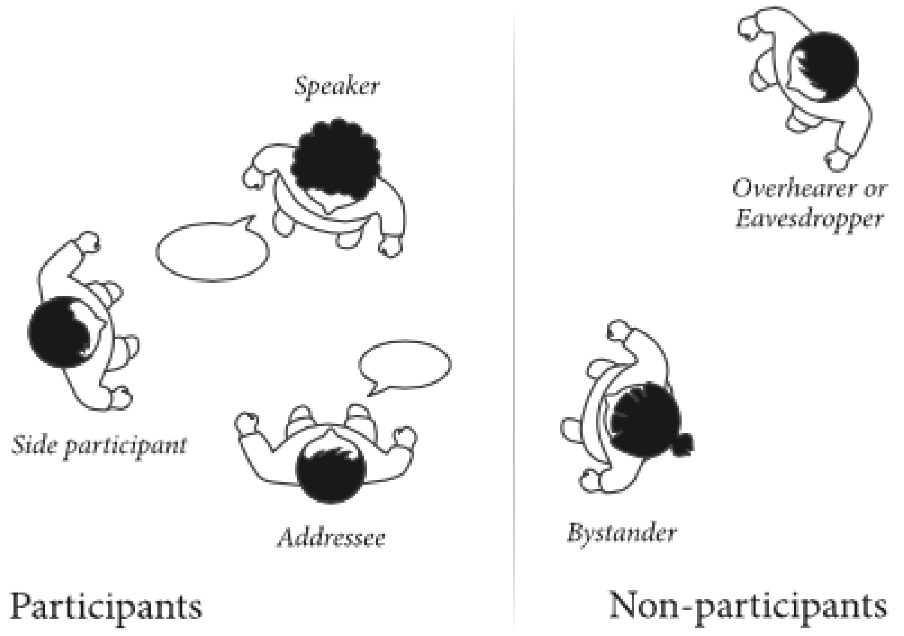

Fig. 1. Levels of conversational participation (adapted from Goffman [1979] and Clark [1996]).

Mutlu, Bilge, Toshiyuki Shiwa, Takayuki Kanda, Hiroshi Ishiguro, and Norihiro Hagita. "Footing in human-robot conversations: how robots might shape participant roles using gaze cues." In Proceedings of the 4th ACM/IEEE international conference on Human robot interaction, pp. 61-68. 2009.

Mutlu, Bilge, Takayuki Kanda, Jodi Forlizzi, Jessica Hodgins, and Hiroshi Ishiguro. "Conversational gaze mechanisms for humanlike robots." ACM Transactions on Interactive Intelligent Systems (TiiS) 1, no. 2 (2012): 1-33.

DATA COLLECTION FOR A GAZE MODEL

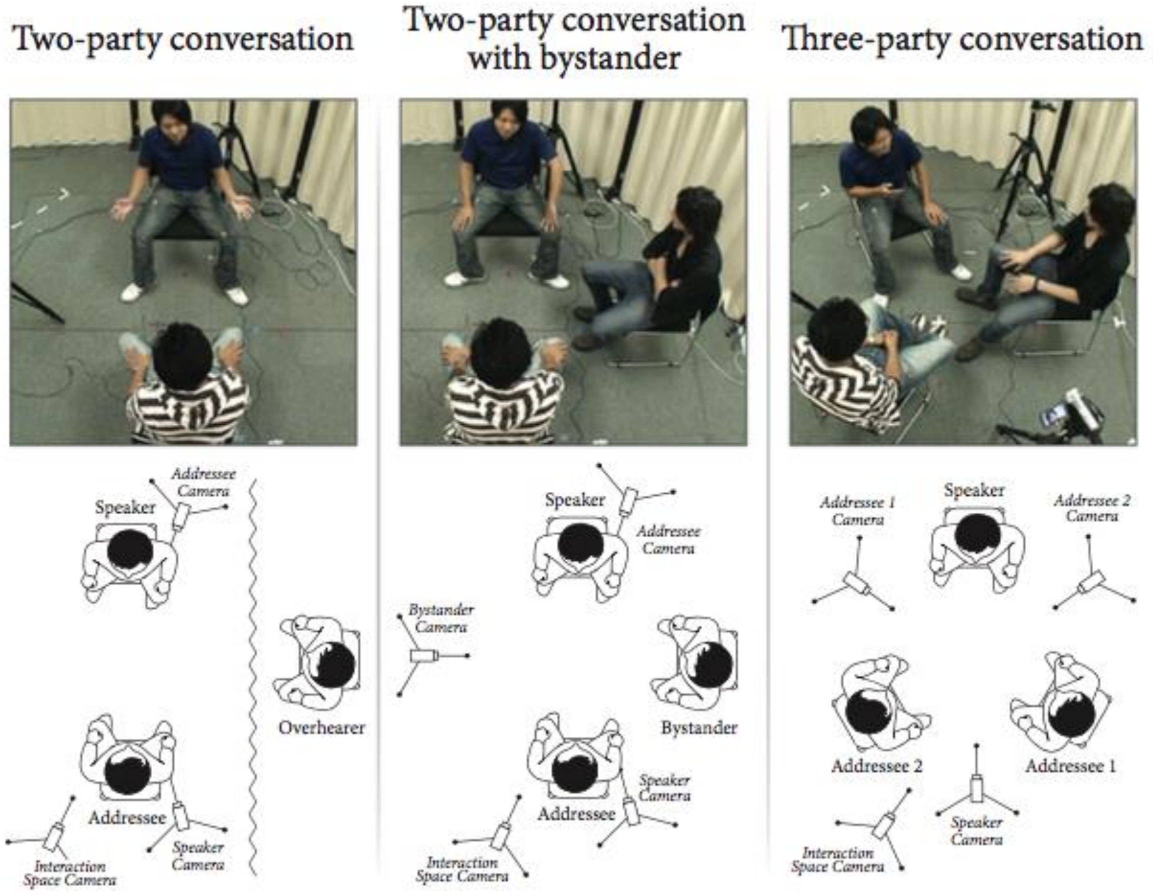

Fig. 2. The data collection setup for the three conversational structures studied: (top) a two-party conversation, (middle) a two-party conversation with a bystander, and (bottom) a three-party conversation.

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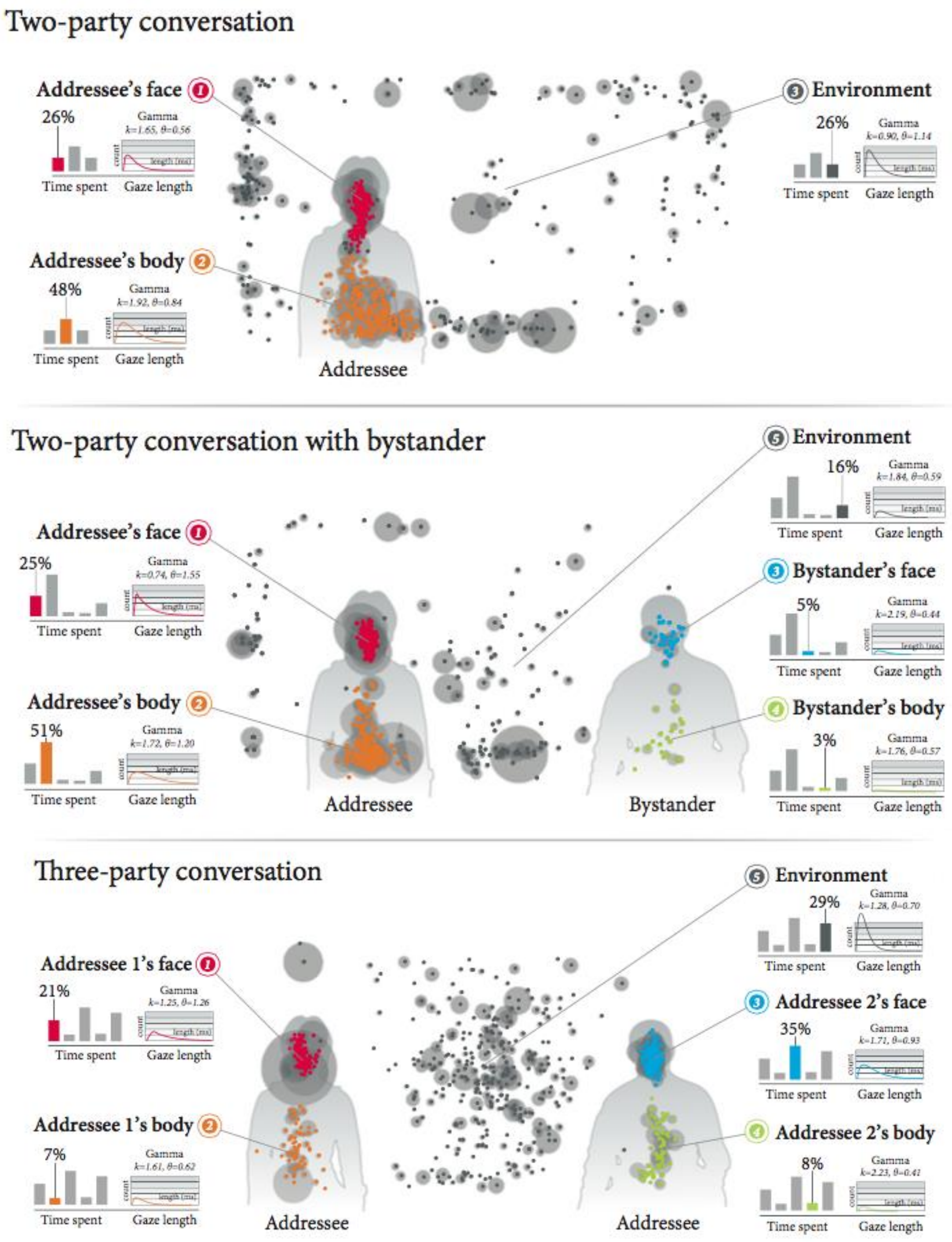
Mutlu, Bilge, Takayuki Kanda, Jodi Forlizzi, Jessica Hodgins, and Hiroshi Ishiguro. "Conversational gaze mechanisms for humanlike robots." ACM Transactions on Interactive Intelligent Systems (TiiS) 1, no. 2 (2012): 1-33.

Data collection for a Gaze model

- **Subjects' gaze behavior** was captured using high-definition cameras placed across from their seats.
- **Subjects' speech was captured** using stereo microphones attached to their collars.
  - The cameras provided video sequences of subjects' faces (from hair to chin).
  - An additional camera on the ceiling was used to capture the interaction space.
  - In total, there were 45 minutes of video for each subject and 180 minutes of data for each triad from four cameras.
- A final analysis included an examination of the video data, calculating the frequencies of and co-occurrences among events, and computing the distribution parameters for the temporal and spatial properties of these events.



Mutlu, Bilge, Takayuki Kanda, Jodi Forlizzi, Jessica Hodgins, and Hiroshi Ishiguro. "Conversationa (TiiS) 1, no. 2 (2012): 1-33.

FROM DATA TO BEHAVIOUR

Three gaze cues were identified to signal the participant roles of his interlocutors.

- *Greetings and summonses.*
- *The body of the conversation.* the speaker spent the majority of his speaking time looking at addressees (74% of the time and the environment 26% of the time in 1st scenario and looked towards the addressee, bystander, and the environment 76%, 8%, and 16% of the time, respectively.
- *Turn-exchanges*

Topic-Signaling Gaze Pattern	Two-party conversations	Three-party conversation
Look away > Look at > Look down	***25%*** at thematic field beginnings ***63%*** at turn beginnings	***29%*** at thematic field beginnings ***7%*** at turn beginnings
Look at > Look down > Look at	***30%*** at thematic field beginnings ***17%*** at turn beginnings	*Not observed*
Look away > Look at > Look away	*Not observed*	***47%*** at thematic field beginnings ***60%*** at turn beginnings
Pattern continuing from previous thematic field	***22%*** at thematic field beginnings ***0%*** at turn beginnings	***22%*** at thematic field beginnings ***0%*** at turn beginnings
No recurring pattern	***22%*** at thematic field beginnings ***21%*** at turn beginnings	***2%*** at thematic field beginnings ***33%*** at turn beginnings

FROM DATA TO BEHAVIOUR:
GAZE PATTERNS BUILT INTO THE SOCIAL ROBOT

Fig. 6. Robovie R-1, the robotic platform we used in the implementation and evaluation of the gaze mechanisms studied in this work.

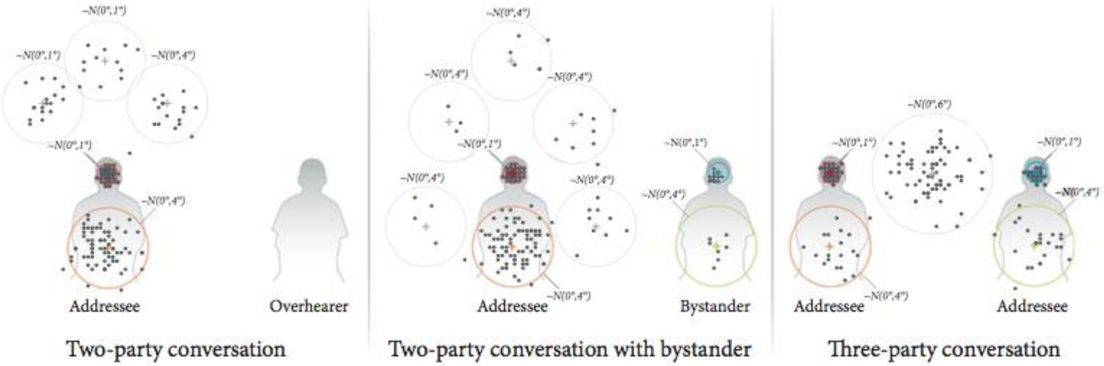


Fig. 7. The gaze targets that the robot produced based on our implementation of the temporal and spatial gaze parameters.

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EVALUATION OF GAZE PATTERNS IMPLEMENTED

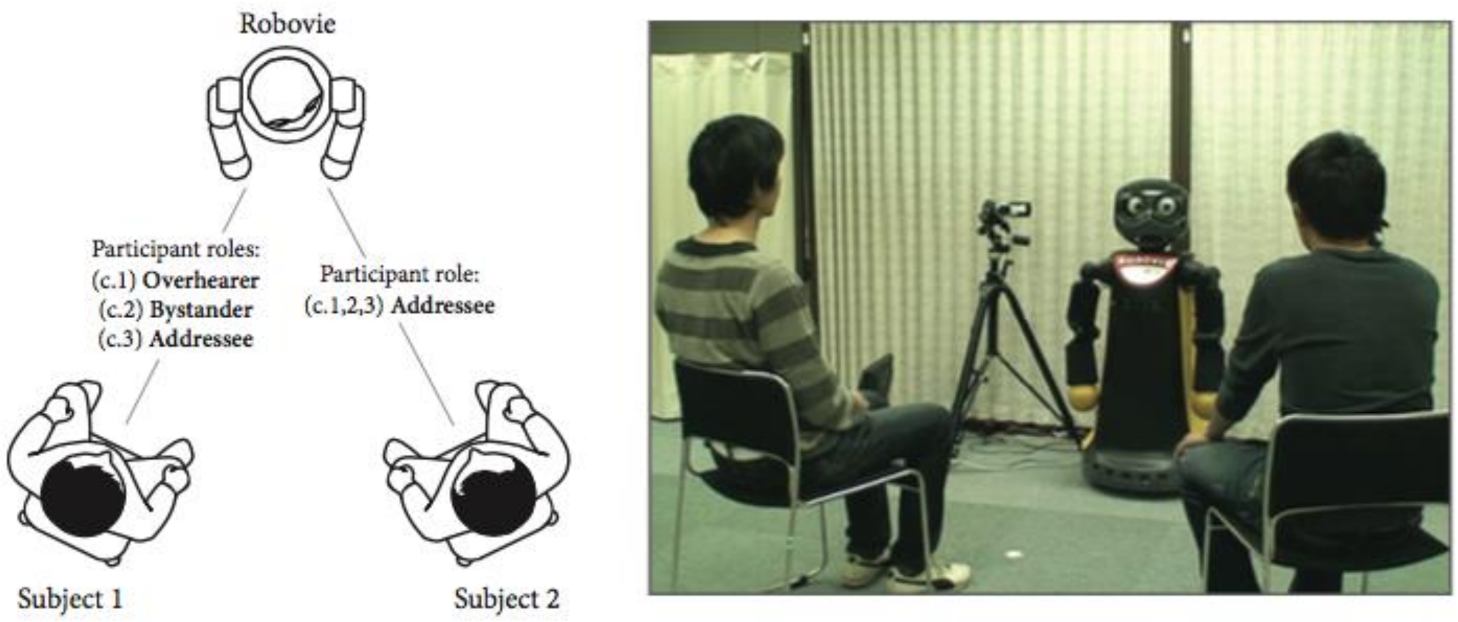

Fig. 9. The spatial setup of the experiment (left) and participants conversing with the robot in an experimental trial (right).

STUDY

Condition* 1.** The robot produced gaze cues for an *addressee* and an *overhearer* (ignoring the individual in the latter role), following the norms of a ***two-party conversation.
Condition* 2.** Gaze cues were produced for an *addressee* and a *bystander*, signaling the participation structure of **a *two-party conversation with bystander.
Condition* 3.** The robot produced gaze cues for *two addressees*, following the participant roles of a ***three-party conversation.

A total of 72 subjects participated in the experiment in 36 trials

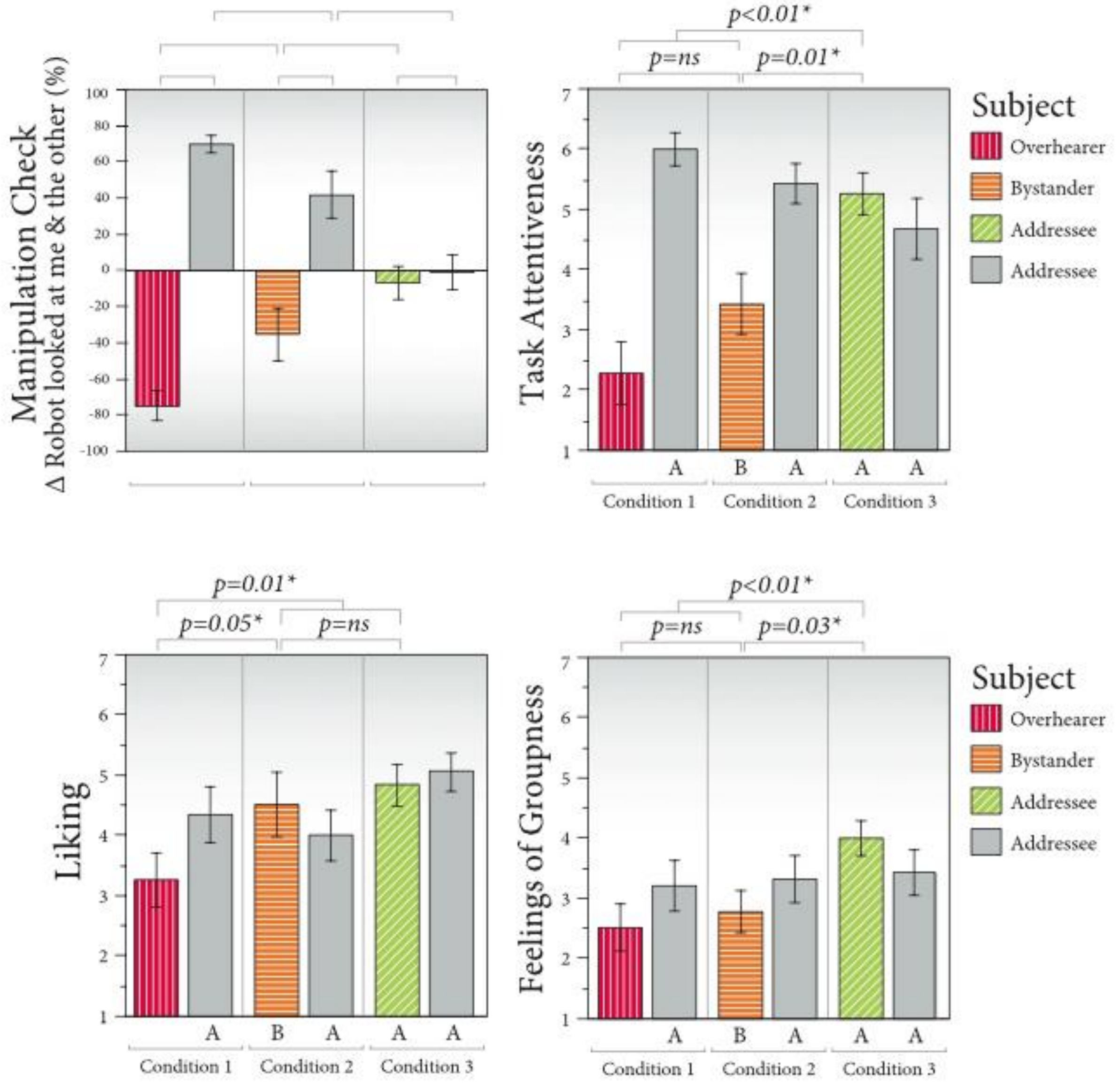

Fig. 11. The objective and subjective measurements.

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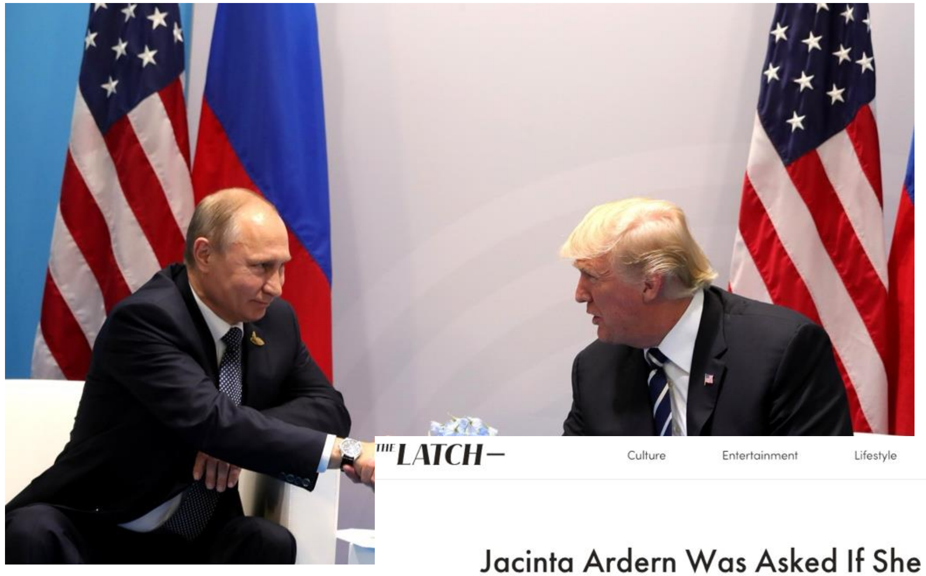
ESTABLISHING SOCIAL RELATIONS: THE POWER OF HANDSHAKES (NON-VERBAL BEHAVIORS….)




THE LATCH—

Culture Entertainment Lifestyle Sustainability Subscribe

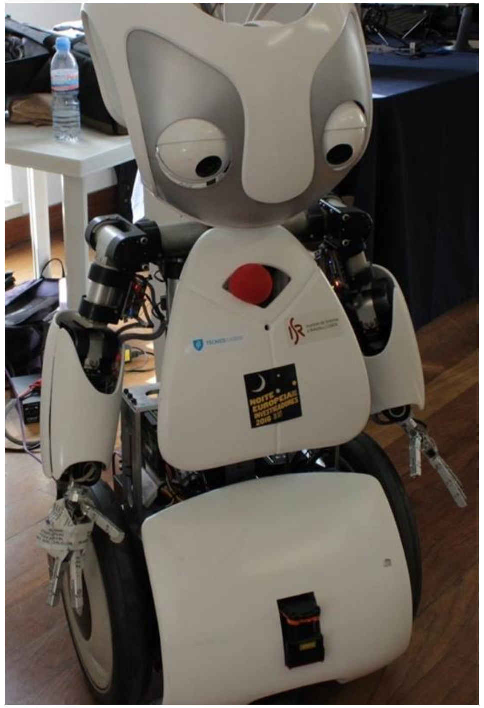
Jacinta Ardern Was Asked If She Met the Finnish PM Because They're Both Young and Female

November 30, 2022

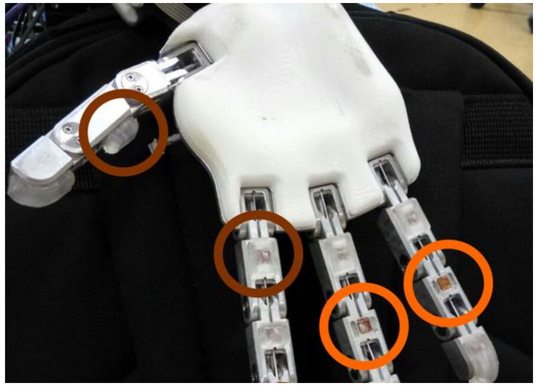
Culture

THE POWER OF A HANDSHAKE

Meet Vizzy



Use Vizzy to understand the power of a handshake in promoting prosocial behaviour.

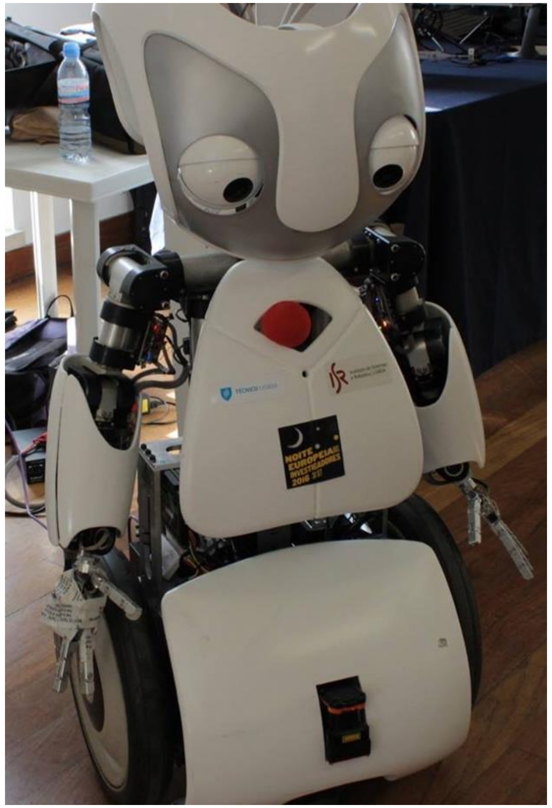


30 degrees of freedom:

- 2 dof's for the mobile base
- 23 dof's for the torso, the arms and hands.
- dof's for the head.

Avelino, J., Moreno, P., Bernardino, A., Correia, F., Paiva, A., Catarino, J., & Ribeiro, P. (2018, October). The Power of a Hand-shake in Human-Robot Interactions. In 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 1864-1869). IEEE.

Creating a human-like handshake



3 phases:

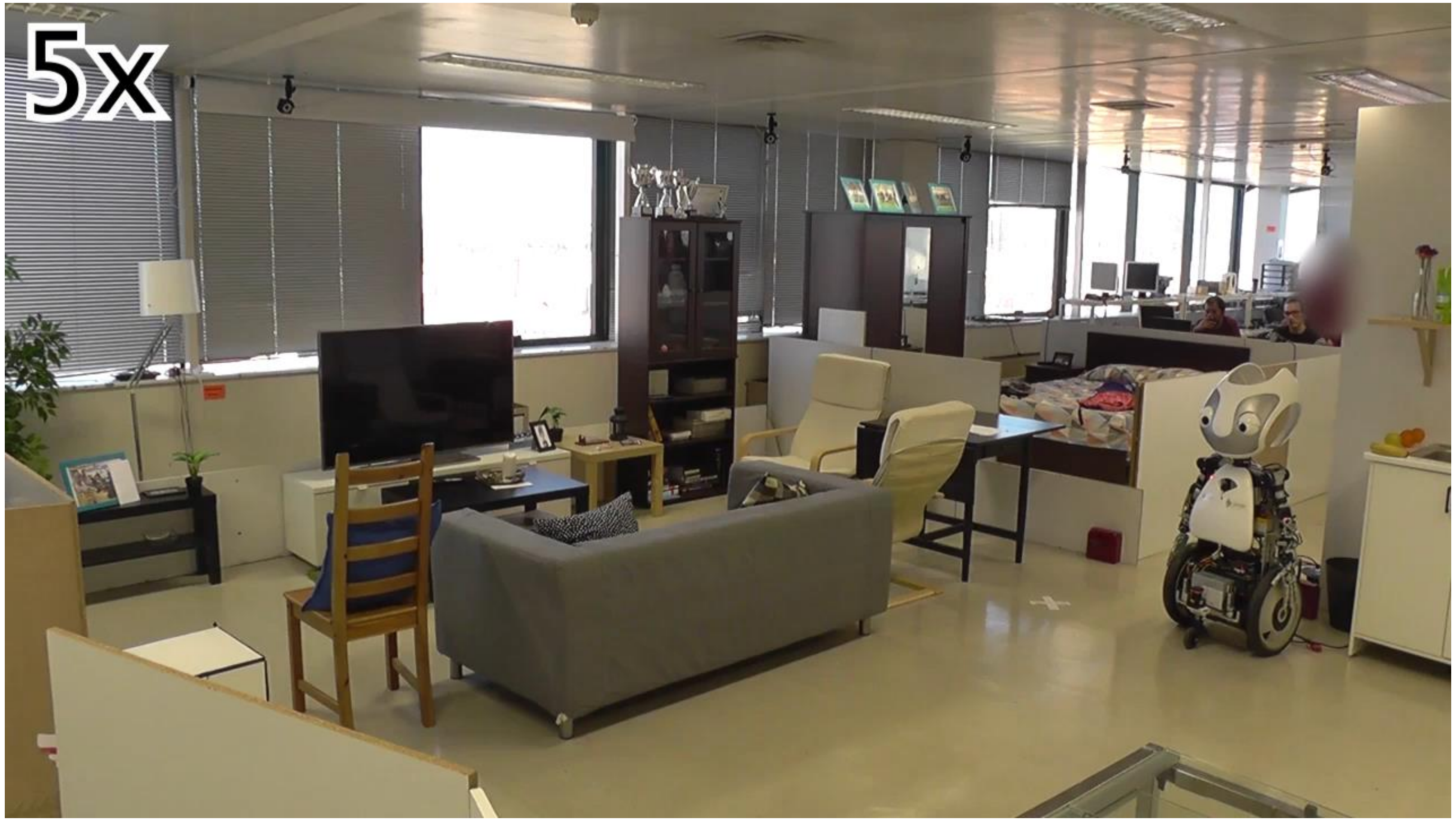
Stretch arm
Handshake
Home position

Arm motion (empirically designed):

- Wrist mean height: 0.84 m
- Amplitude: 2 cm
- Frequency: 1.7 Hz

Hand grip: average joint positions from an hand-grip comfort study with 35 participants:

Avelino, J., Moreno, P., Bernardino, A., Correia, F., Paiva, A., Catarino, J., & Ribeiro, P. (2018, October). The Power of a Hand-shake in Human-Robot Interactions. In 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 1864-1869). IEEE.



Task (four steps):

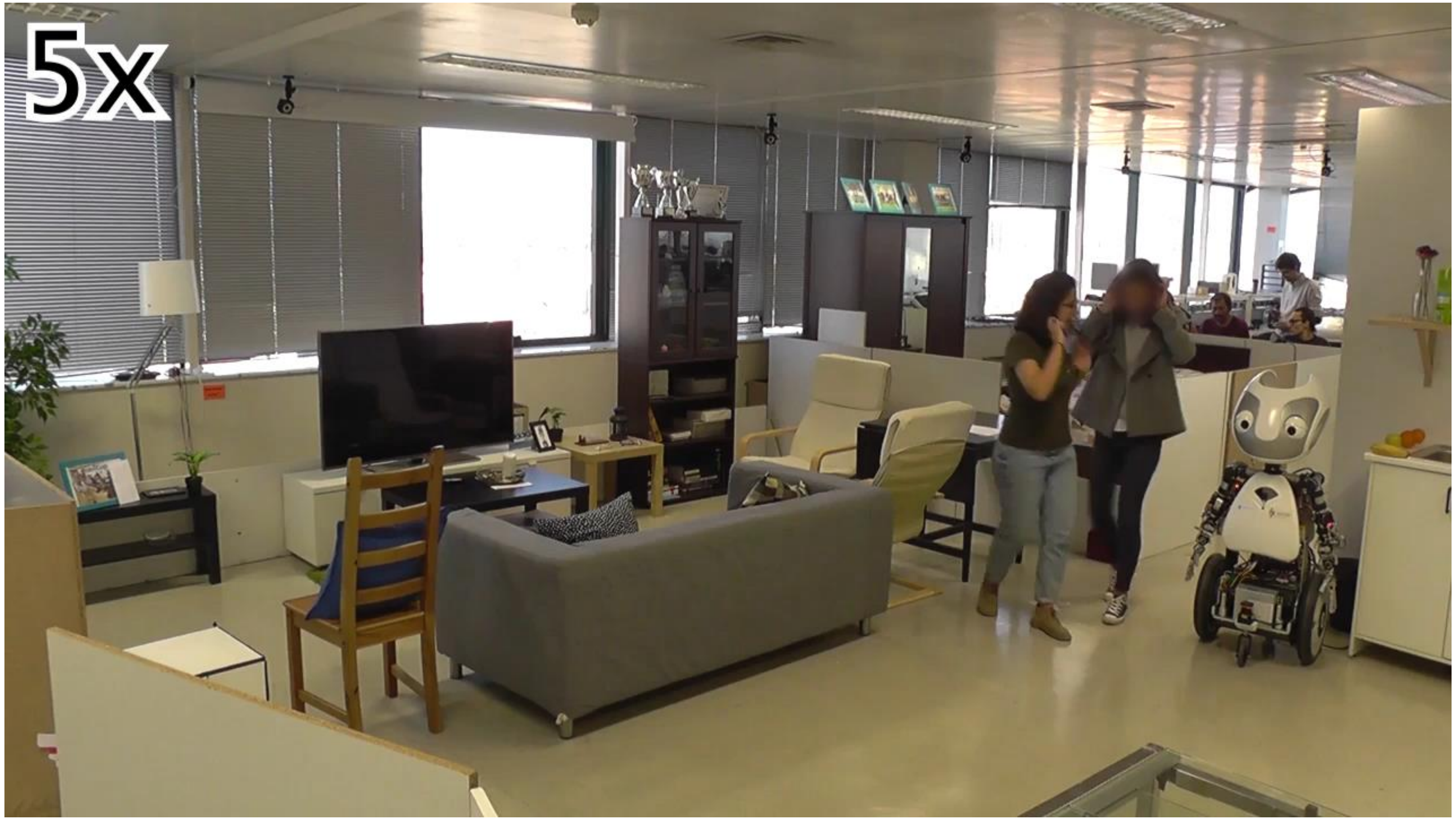
(1) stand in the initial position and say out loud the voice command “I am going to start”;

(2) (2) move to the target position where a picture with several geometric shapes is;

(3) (3) count how many triangles there is on the picture;

(4) (4) return to the initial position and say out loud “I saw [N] triangles”.

Avelino, J., Moreno, P., Bernardino, A., Correia, F., Paiva, A., Catarino, J., & Ribeiro, P. (2018, October). The Power of a Hand-shake in Human-Robot Interactions. In 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 1864-1869). IEEE.



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Study

- 2 conditions: with and without a handshake

Results

Measures:
RoSAS (The Robotic Social Attributes Scale):
- Warmth (e.g., “feeling”)
- Competence (e.g., “capable”)
- Discomfort (e.g., “awkward”)

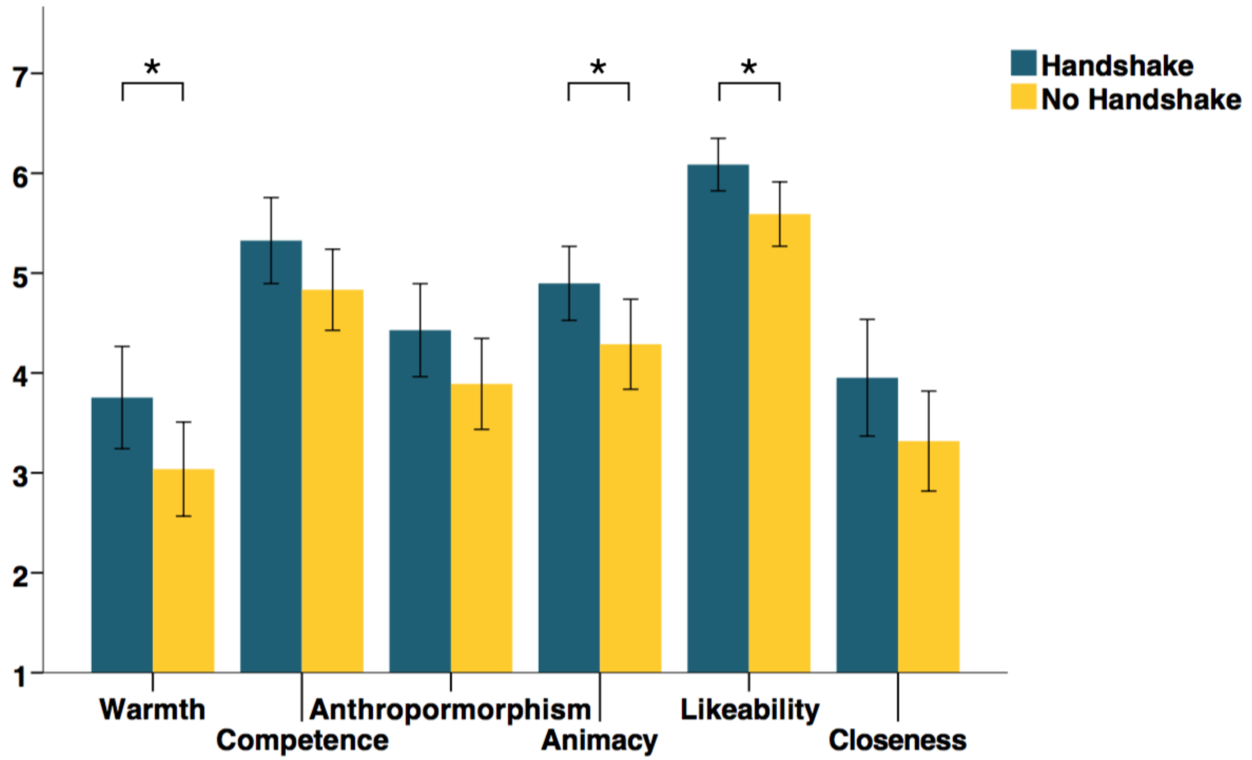
Godspeed questionnaire:
- Anthropomorphism (e.g., “fake/natural”)
- Animacy (e.g., “stagnant/lively”)
- Likeability (e.g., “unpleasant/pleasant”)

Perceived closeness

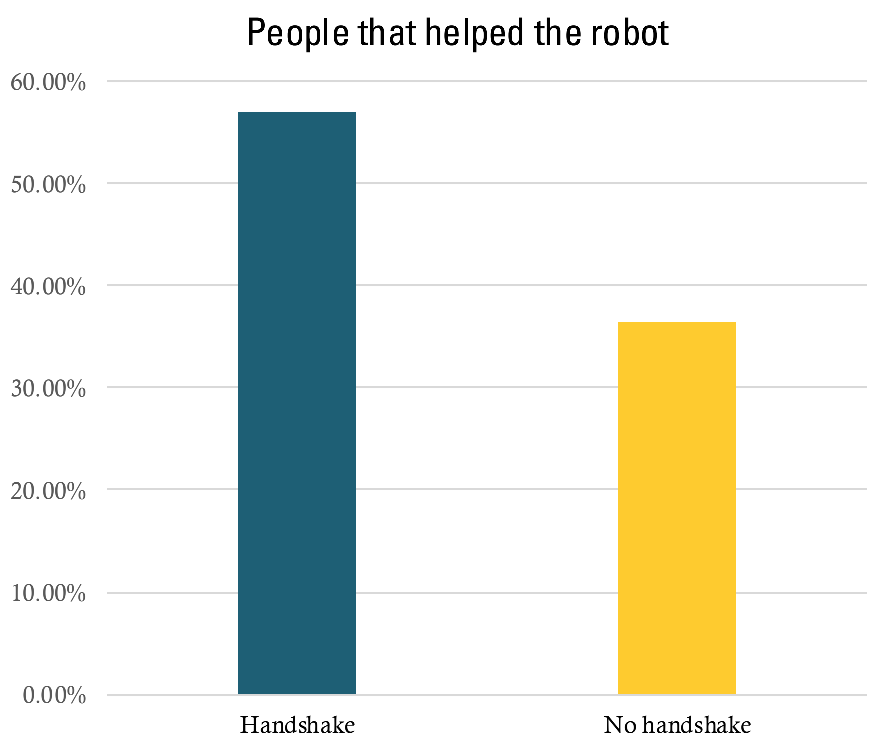
Help behaviour

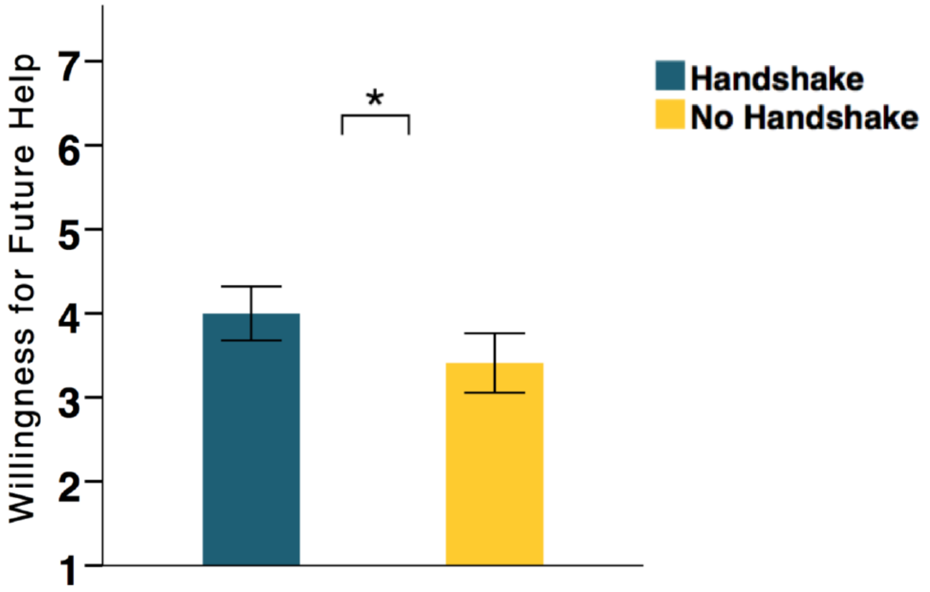
Perception that the robot needs help

Willingness to help in the future



THE POWER OF A HANDSHAKE IN PROSOCIAL ROBOTICS





Study carried out with 43 university students (two conditions) using a between subjects experimental design.

Avelino, J., Moreno, P., Bernardino, A., Correia, F., Paiva, A., Catarino, J., & Ribeiro, P. (2018, October). The Power of a Hand-shake in Human-Robot Interactions. In 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 1864-1869). IEEE.

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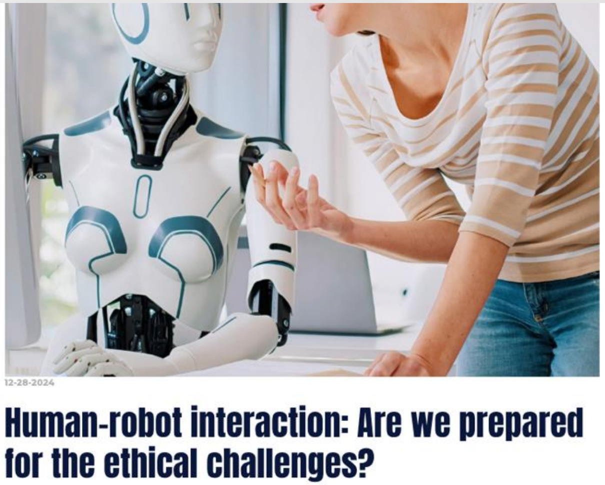

ETHICAL CONCERNS OF EMOTIONAL & NVB IN ROBOTS

- **Over-reliance and dependence-** robotic companions or caregivers designed to be “emotionally” and “human-like” supportive may foster deep emotional dependence, particularly in children or lonely and elderly adults, replacing human relationships.
- **Deception and Trust-** simulated emotions & NVB can be manipulative and used for persuasion purposes. Users may believe that the robot "cares" for them and may trust it more than they should, leading to vulnerability or exploitation.
- **Misrepresentation of intelligence-** people may confuse emotional & NV display with genuine consciousness and sentience.

PAPERS TO READ

- Rosenthal-von der Pütten, A. M., Krämer, N. C., Hoffmann, L., Sobieraj, S., & Eimler, S. C. (2013). An experimental study on emotional reactions towards a robot. International Journal of Social Robotics, 5(1), 17-34.
- Seo, S. H., Geiskkovitch, D., Nakane, M., King, C., & Young, J. E. (2015, March). Poor Thing! Would You Feel Sorry for a Simulated Robot?: A comparison of empathy toward a physical and a simulated robot. In Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (pp. 125-132). ACM.
- Iolanda Leite, André Pereira, Samuel Mascarenhas, Carlos Martinho, Rui Prada, Ana Paiva: The influence of empathy in human-robot relations. Int. J. Hum.-Comput. Stud. 71(3): 250-260 (2013)
- Iolanda Leite, Ginevra Castellano, André Pereira, Carlos Martinho, Ana Paiva: Modelling empathic behaviour in a robotic game companion for children: an ethnographic study in real-world settings. HRI 2012.
- Cauchard, J. R., Zhai, K. Y., Spadafora, M., & Landay, J. A. (2016, March). Emotion encoding in human-drone interaction. In 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI) (pp. 263-270). IEEE.
- Mutlu, Bilge, Toshiyuki Shiwa, Takayuki Kanda, Hiroshi Ishiguro, and Norihiro Hagita. "Footing in human-robot conversations: how robots might shape participant roles using gaze cues." In Proceedings of the 4th ACM/IEEE international conference on Human robot interaction, pp. 61-68. 2009.
- Mutlu, Bilge, Takayuki Kanda, Jodi Forlizzi, Jessica Hodgins, and Hiroshi Ishiguro. "Conversational gaze mechanisms for humanlike robots." ACM Transactions on Interactive Intelligent Systems (TiiS) 1, no. 2 (2012): 1-33.
- Avelino, J., Moreno, P., Bernardino, A., Correia, F., Paiva, A., Catarino, J., & Ribeiro, P. (2018, October). The Power of a Hand-shake in Human-Robot Interactions. In 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 1864-1869). IEEE.