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CHALMERS
UNIVERSITY OF TECHNOLOGY

The sound of trust in Human-Robot Interaction

Dr. Ilaria Torre
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2008-2011
Bachelor's
Languages and
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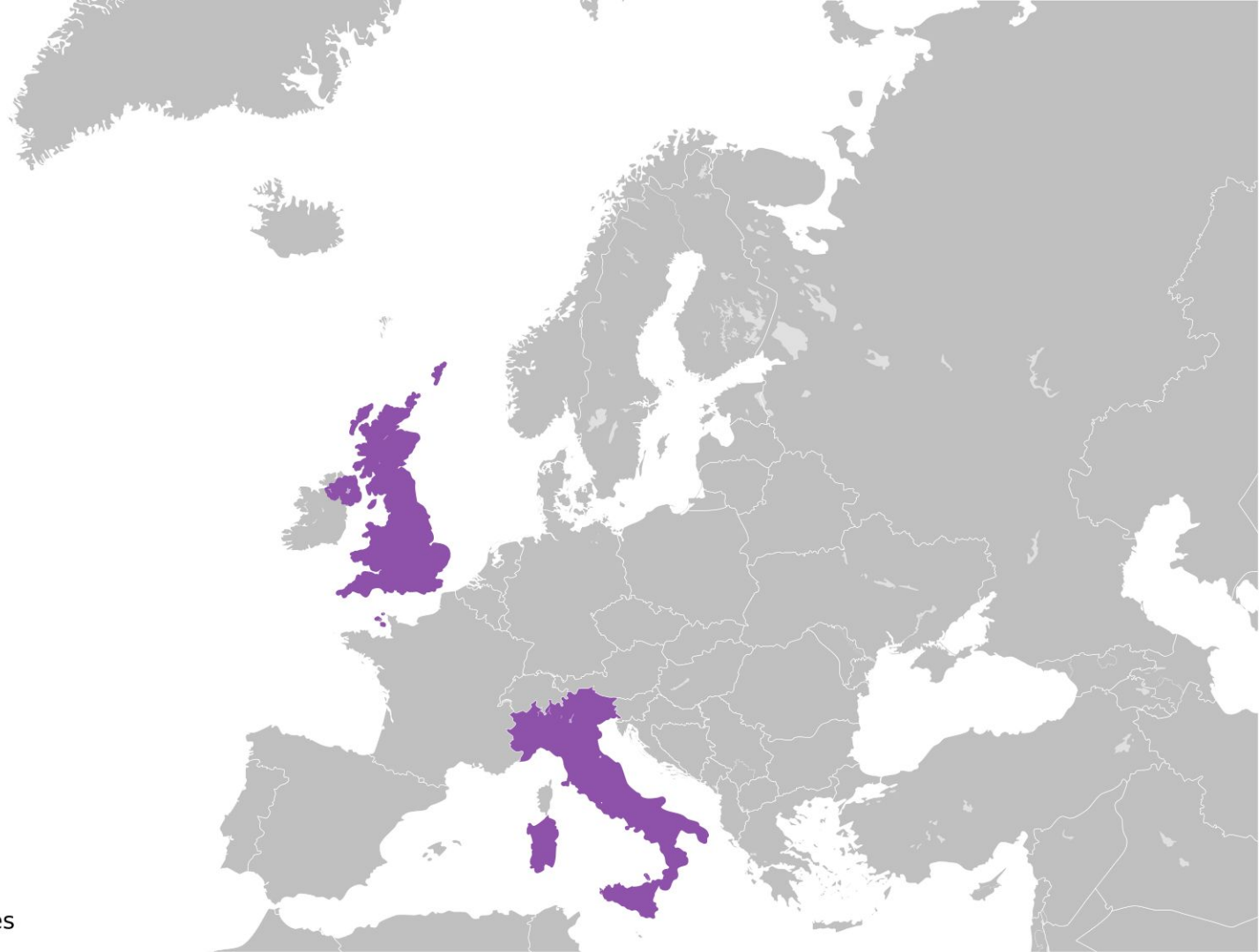

2012-2013
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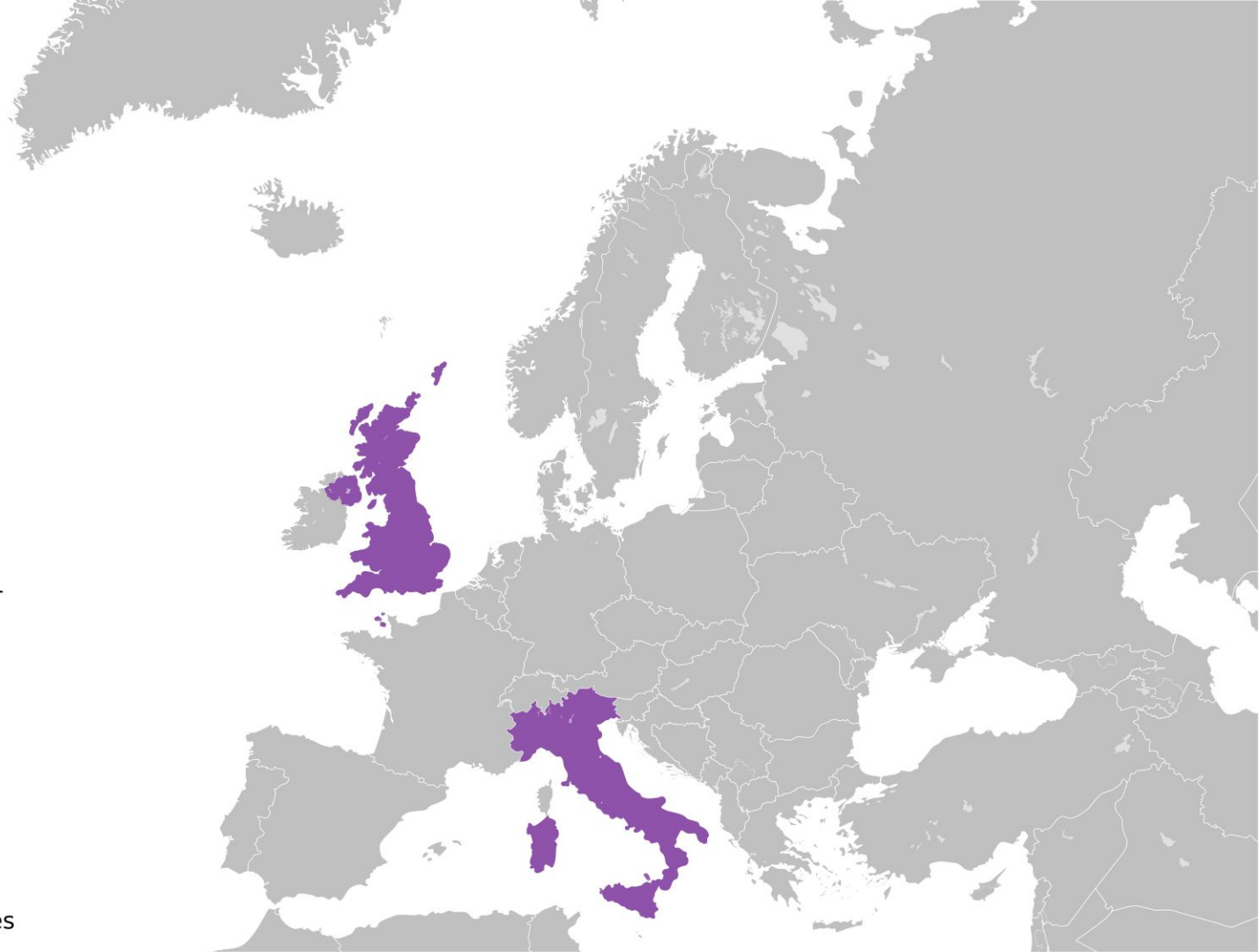

UNIVERSITY OF PLYMOUTH

2014-2017
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Human-Computer Interaction

UNIVERSITY of York

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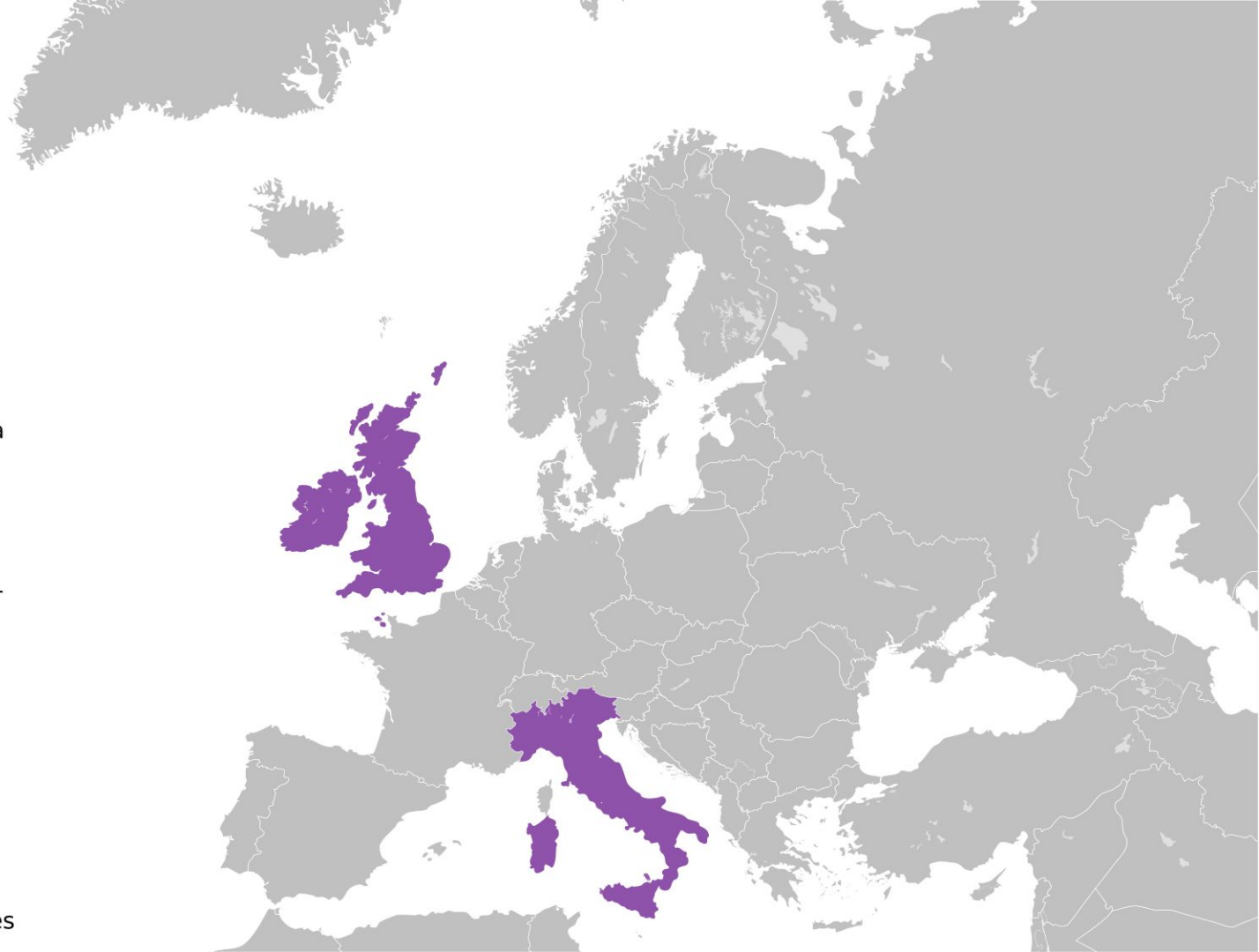

Trinity College Dublin
The University of Dublin

2017-2019
Marie-Skłodowska Curie Fellowship

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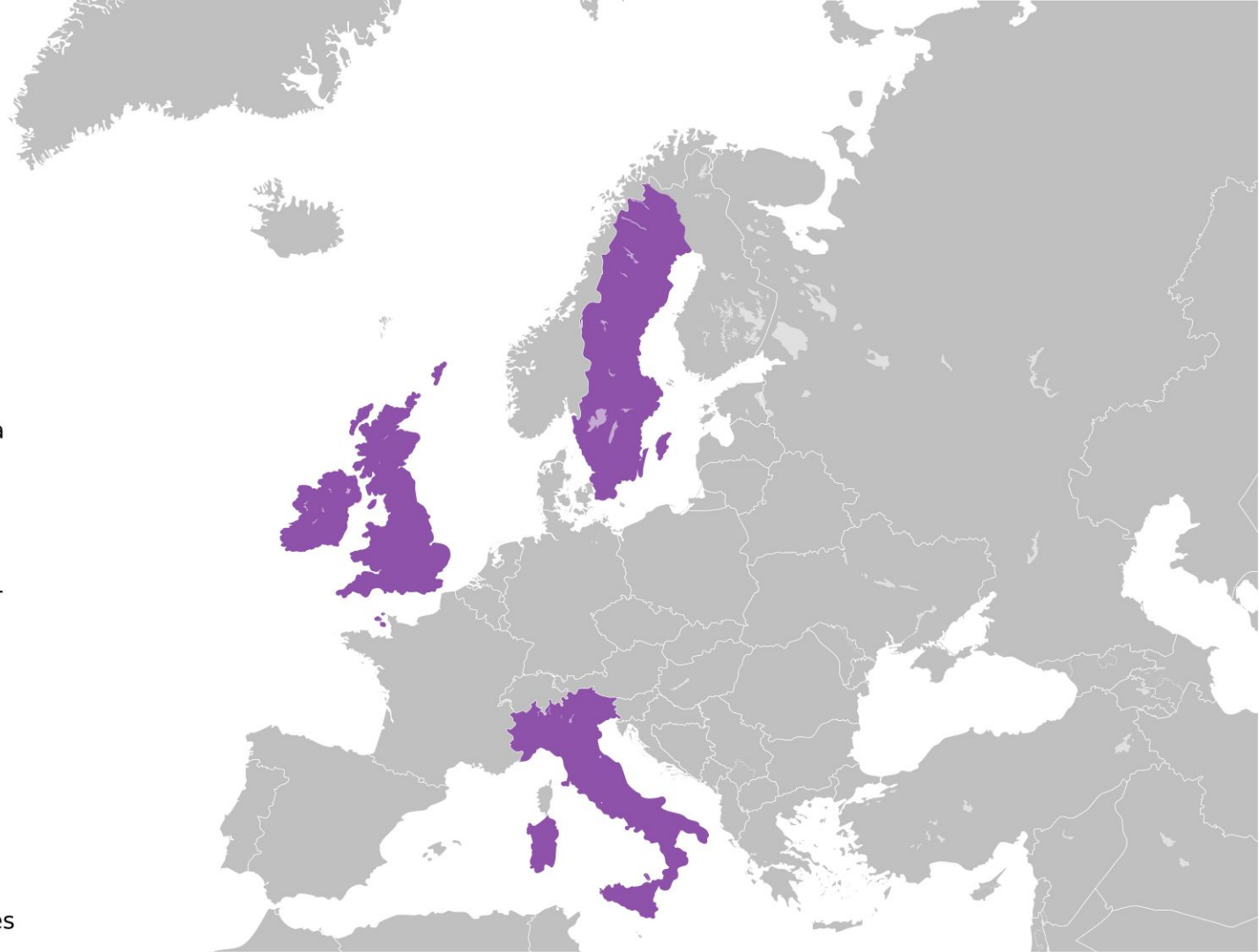

2020-2023
Postdoctoral
researcher

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Curie Fellowship

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2023-
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professor

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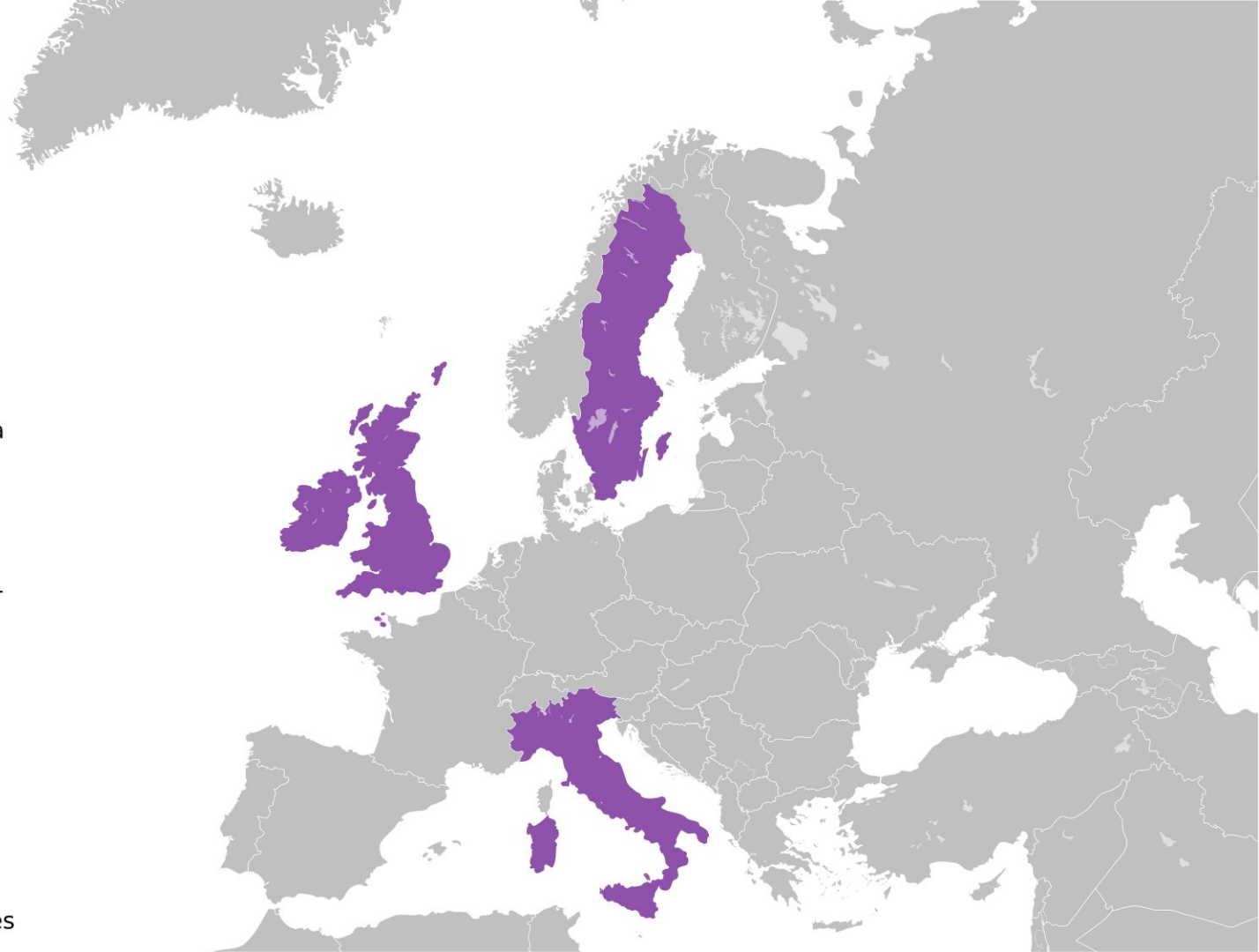
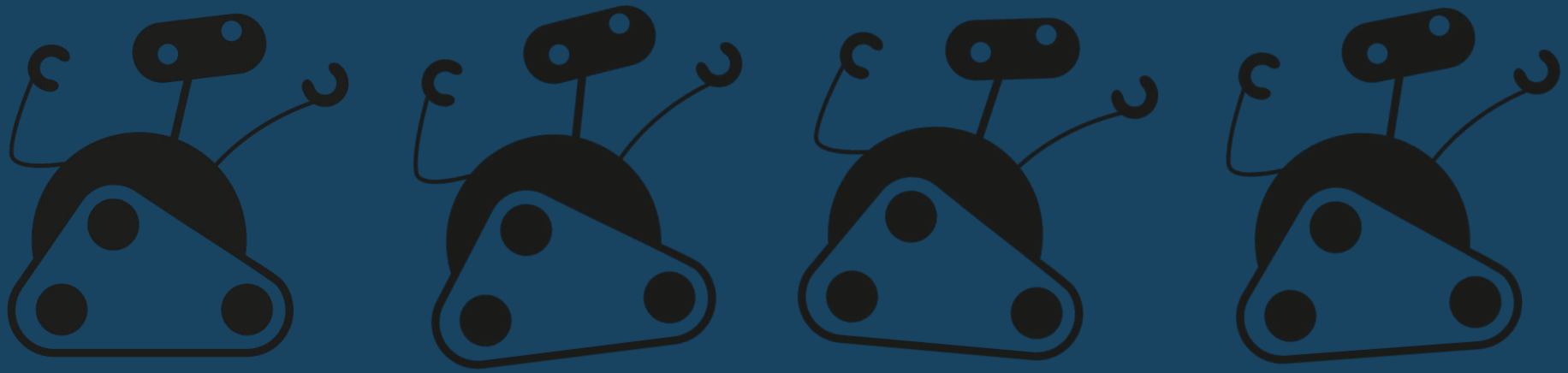
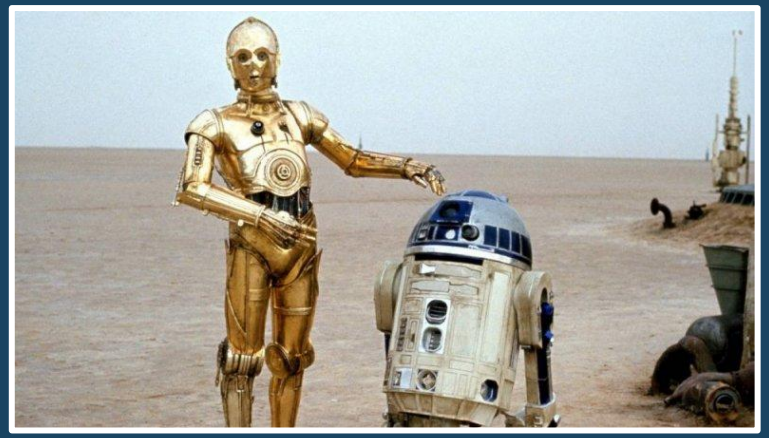
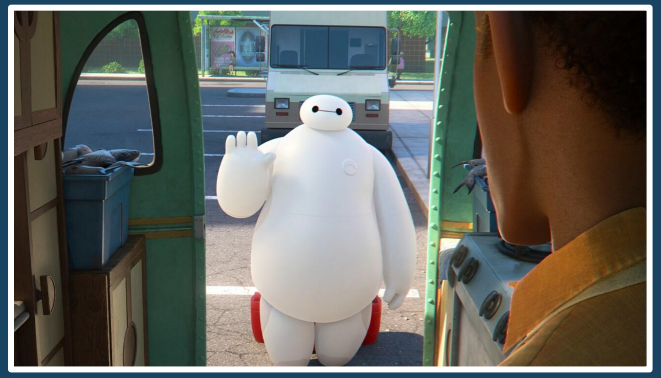


Robots



Robots

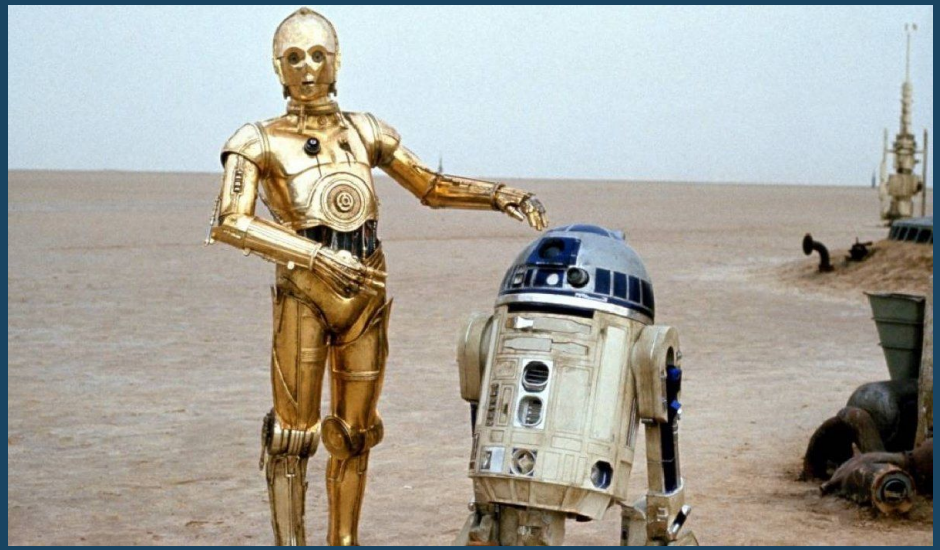




What is a robot?

- From Czech writer Karel Čapek — who was the first to use the term 'robot' in 1921
- Science Fiction: Asimov, Philip K. Dick, George Lucas...

Imaged by Heritage Auctions, HA.com



What is a robot?

A definition:

"A machine that is programmable by a computer, capable of carrying out a complex series of actions automatically."

What is a social robot?

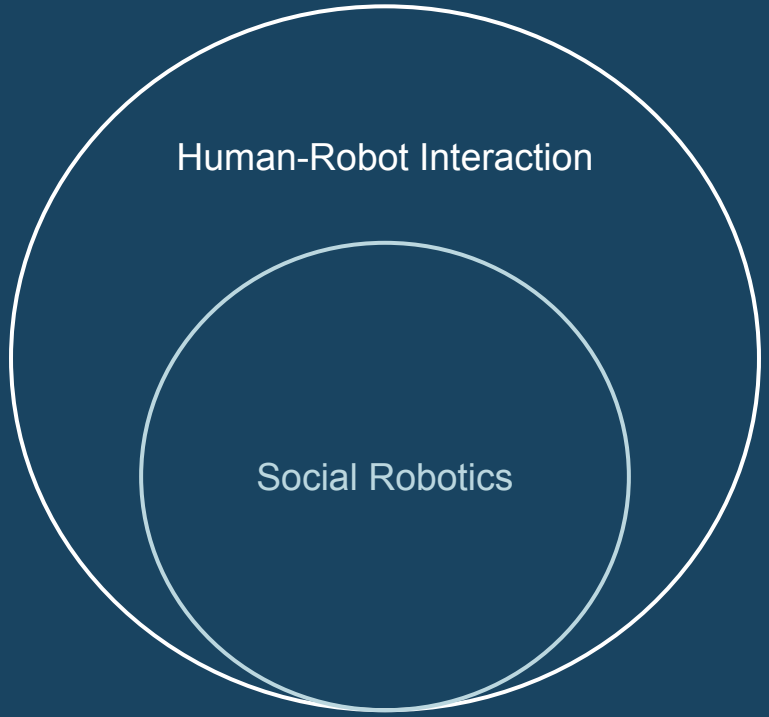
A definition:

"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, K. & Billard, A. (1999). Bringing up robots or – the psychology of socially intelligent robots: From theory to implementation. *Proceedings of the Autonomous Agents*

Social Robotics vs. Human-Robot Interaction



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Human-Robot Interaction

Understanding users

- Design, analyze and document Human-Robot Interaction (HRI) experiments

Designing and developing Robot Systems

- Understanding user needs and requirements
- Use state-of-the-art software architectures and tools to develop social robotic applications

- Demonstrate an insight into the societal and ethical aspects of the design, development, evaluation and deployment of social robots.

Application areas

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 (dangerous or inaccessible)	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, autonomous, which can be therapy partners or therapeutic playmates	Social skills of the robot and acceptance very important. Safety and ethical issues also important.

Application areas

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Trust in HRI

- Trust is an attitude that an agent will perform as expected and can be relied upon to reach its goal in a situation characterized by uncertainty and vulnerability

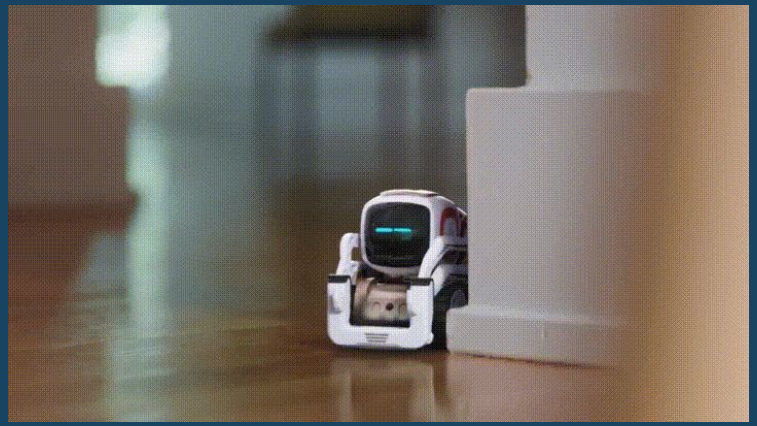
- Trust can be quickly gained (automation bias) but also quickly lost…

Natarajan, M. & Gombolay, M. (2020). Effects of anthropomorphism and accountability on trust in human robot interaction. In *Proceedings of HRI*.

Trust in HRI

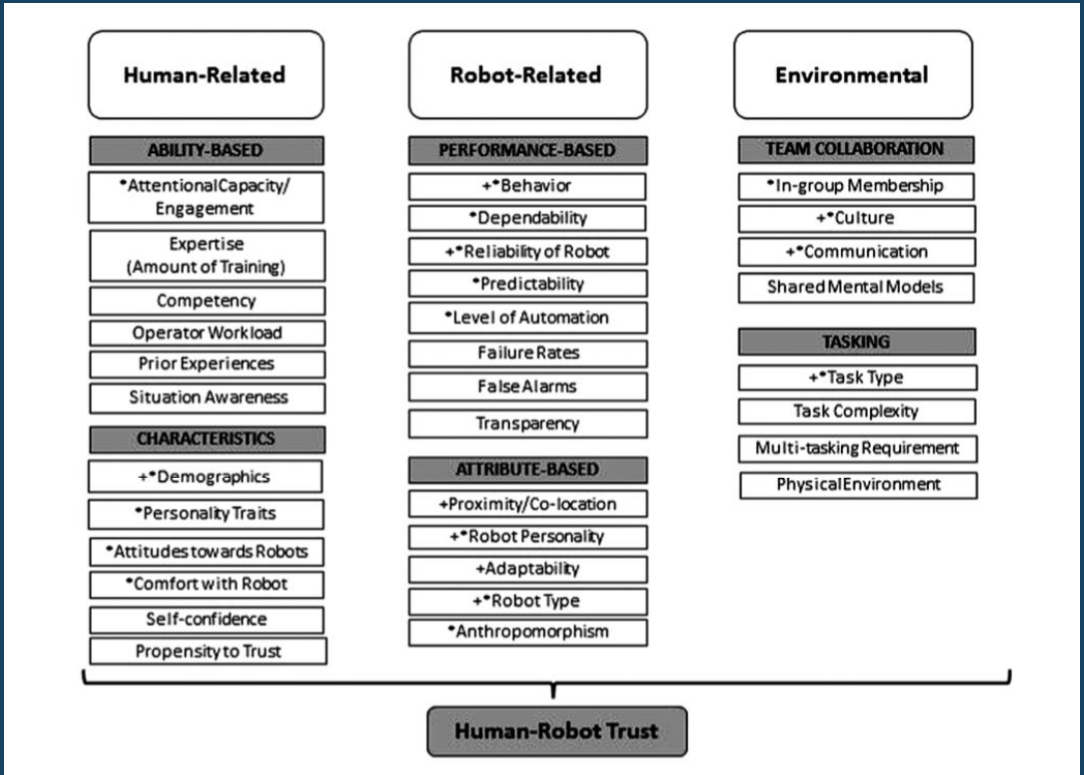
- Competence-based trust

- Relation-based trust



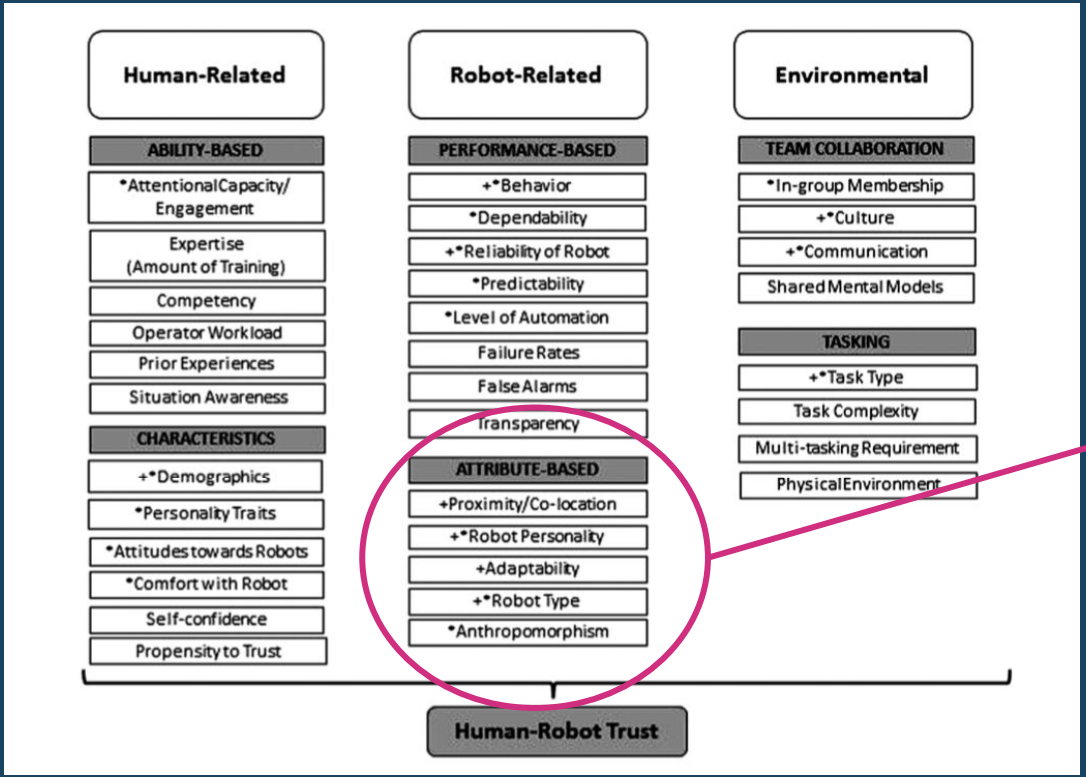
Malle, B. F., & Ullman, D. (2021). A multidimensional conception and measure of human-robot trust. In *Trust in human-robot interaction* (pp. 3-25). Academic Press.

Trust in HRI



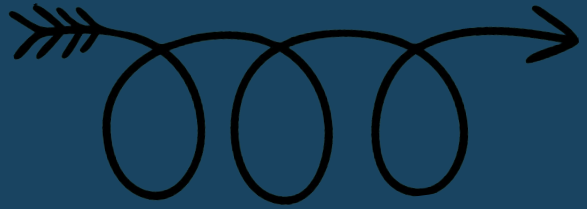
Hancock, P, Billings, D. et al. (2011). A meta-analysis of factors affecting trust in human-robot interaction. *Human factors, vol. 53*, pp. 517–27.

Trust in HRI



Hancock, P, Billings, D. et al. (2011). A meta-analysis of factors affecting trust in human-robot interaction. *Human factors, vol. 53*, pp. 517–27.

First impression x behaviour



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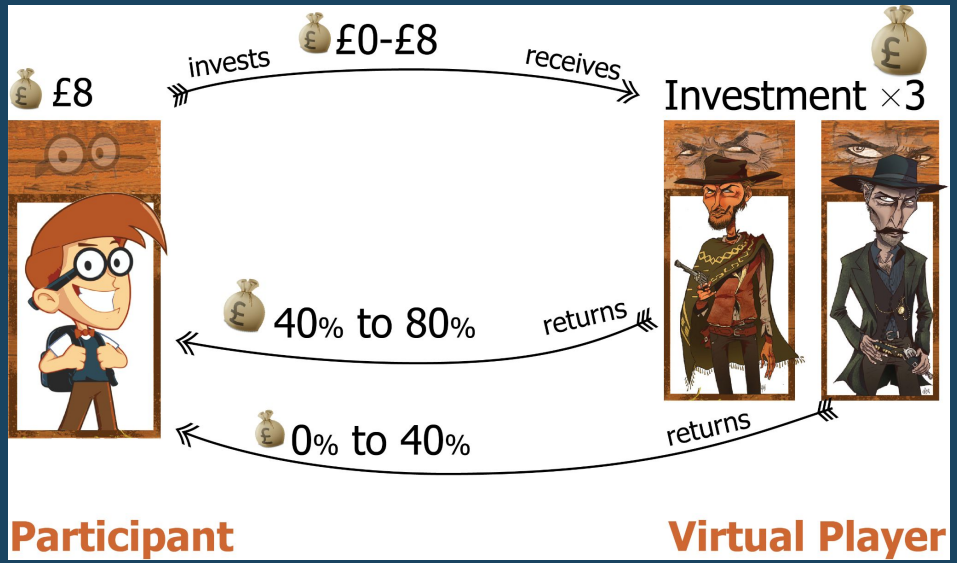
The investment game

- Implicit measure of (economic) trust
- Can be used as a single measure, but also over time (repeated investment game)



Torre, I., Goslin, J., & White, L. (2020). If your device could smile: People trust happy-sounding artificial agents more. *Computers in Human Behavior, 105*, 106215.

Trust towards accented virtual agents

Experiment 1:

- SSBE vs. Liverpool accent
- Trustworthy vs. untrustworthy agent
- 20 rounds
- N = 44 British participants

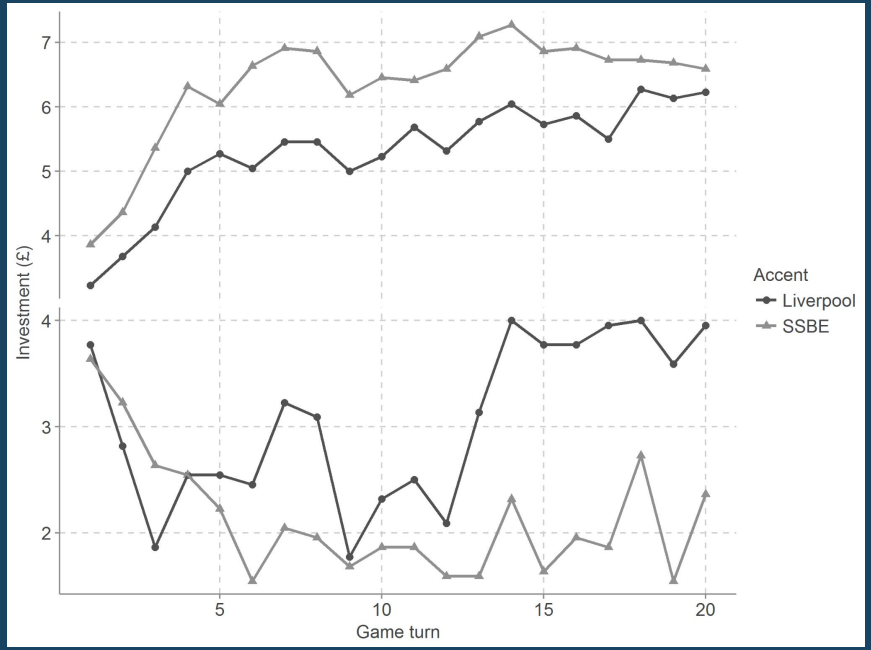
Torre, I., Goslin, J., & White, L. (2015). Investing in accents: How does experience mediate trust attributions to different voices?. In *proc. ICPhS 2015.*

Trust towards accented virtual agents

- Higher investments to trustworthy agent
- Higher overall investments to SSBE

- Within generous condition:
  - Higher investments to SSBE

- Within mean condition:
  - Lowest investments to SSBE
  - Increased investments to Liverpool



Torre, I., Goslin, J., & White, L. (2015). Investing in accents: How does experience mediate trust attributions to different voices?. In *proc. ICPhS 2015.*

Trust towards accented virtual agents

Experiment 2:

- SSBE vs. Birmingham vs. London vs. Plymouth
- 4 speakers x accent
- Trustworthy vs. untrustworthy agent
- 20 rounds
- N = 108 British participants

Torre, I., White, L., Goslin, J., & Knight, S. (2024). The irrepressible influence of vocal stereotypes on trust. *Quarterly Journal of Experimental Psychology, 77*(10)

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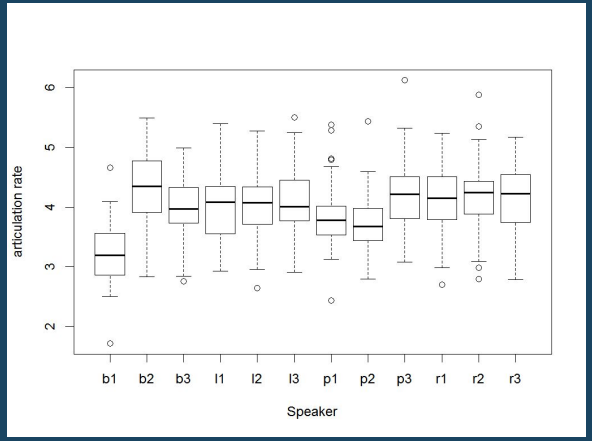
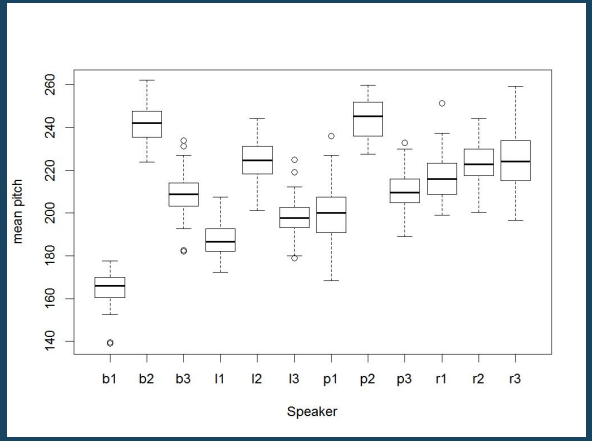




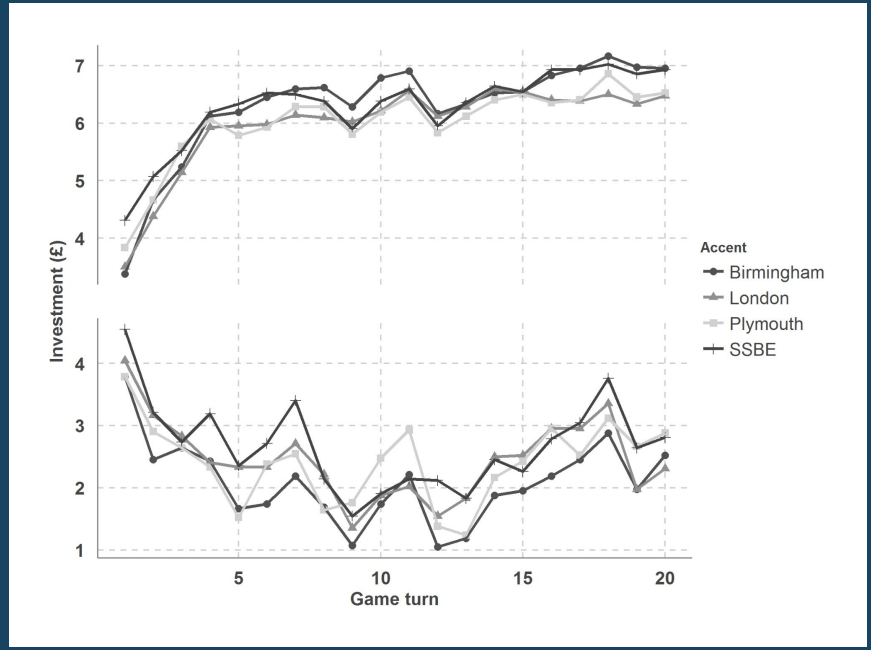
Torre, I., White, L., Goslin, J., & Knight, S. (2024). The irrepressible influence of vocal stereotypes on trust. *Quarterly Journal of Experimental Psychology, 77*(10)

Trust towards accented virtual agents

- Higher investments to generous agent
- Higher overall investments to SSBE

- Within generous condition:
  - Higher investments to SSBEand Birmingham

- Within mean condition:
  - Lowest investments to Birmingham



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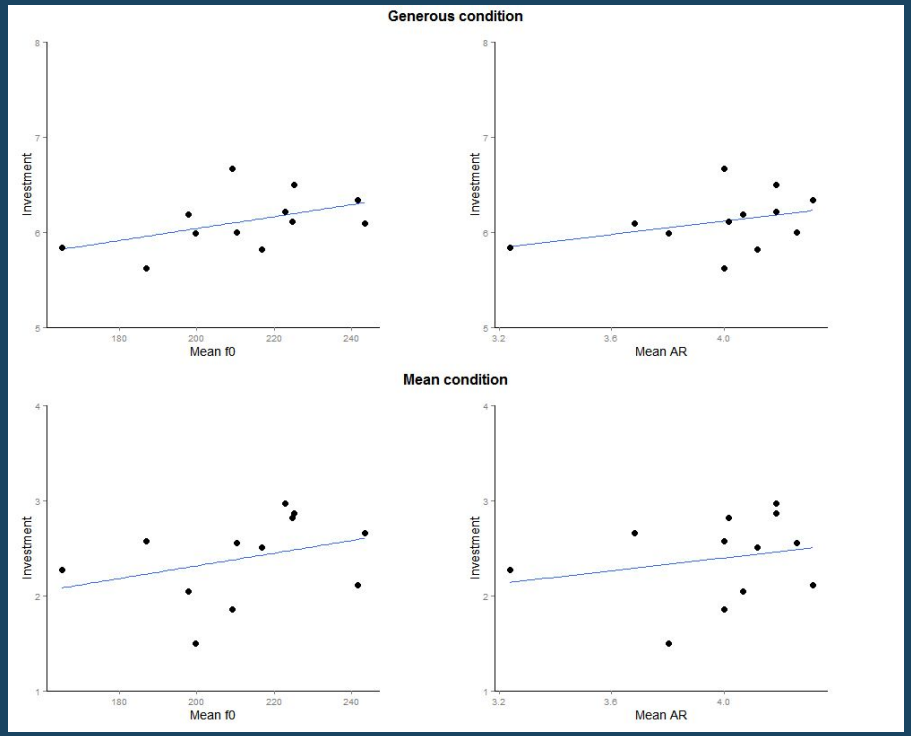
Trust towards accented virtual agents



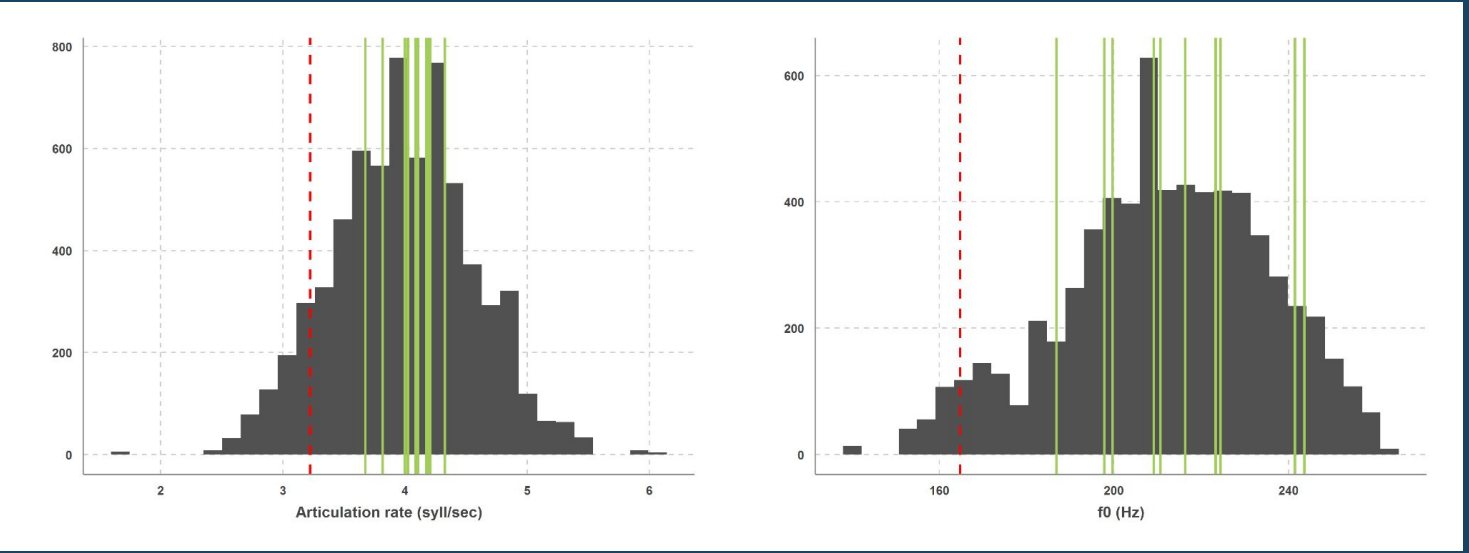
- Higher investments to fast speakers
- Higher investments to high-pitched speakers

Torre, I., White, L., Goslin, J., & Knight, S. (2024). The irrepressible influence of vocal stereotypes on trust. *Quarterly Journal of Experimental Psychology, 77*(10)

Trust towards accented virtual agents

One outlier voice drove the results! Eliminating it we found:

- Higher investments to slow speakers
- No effect of pitch



Torre, I., White, L., Goslin, J., & Knight, S. (2024). The irrepressible influence of vocal stereotypes on trust. *Quarterly Journal of Experimental Psychology, 77*(10)

Trust towards pitch-modified virtual agents

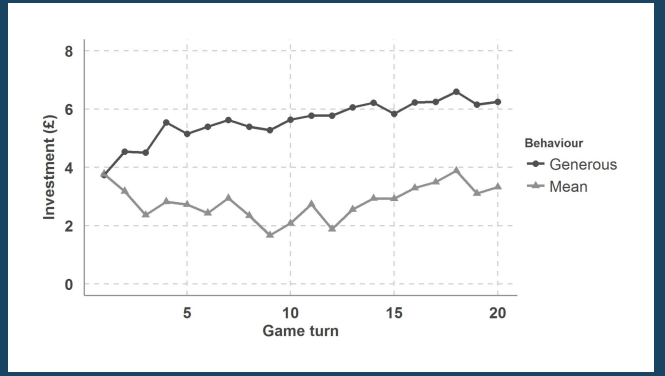
Experiment 3:

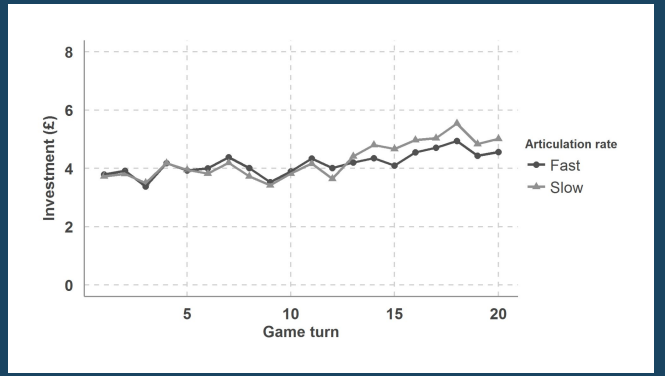
- 1 x male SSBE speaker, 1 x female SSBE speaker
- Pitch and rate artificially increased and decreased (by 15% and 10%)
- Trustworthy vs. untrustworthy agent
- 20 rounds
- N = 120 British participants

	Female	Male
Original f0 (Hz)	229	122
Raised f0 (Hz)	265	141
Lowered f0 (Hz)	198	107
Original rate (syll/sec)	4.3	4.1
Increased rate (syll/sec)	4.6	4.38
Decreased rate (syll/sec)	4.04	3.95

Trust towards pitch-modified virtual agents

- Higher investments to generous agent
- Higher investments to high f0
- Higher investments to female speaker
- Higher investments to slow rate





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Trust towards accented robots

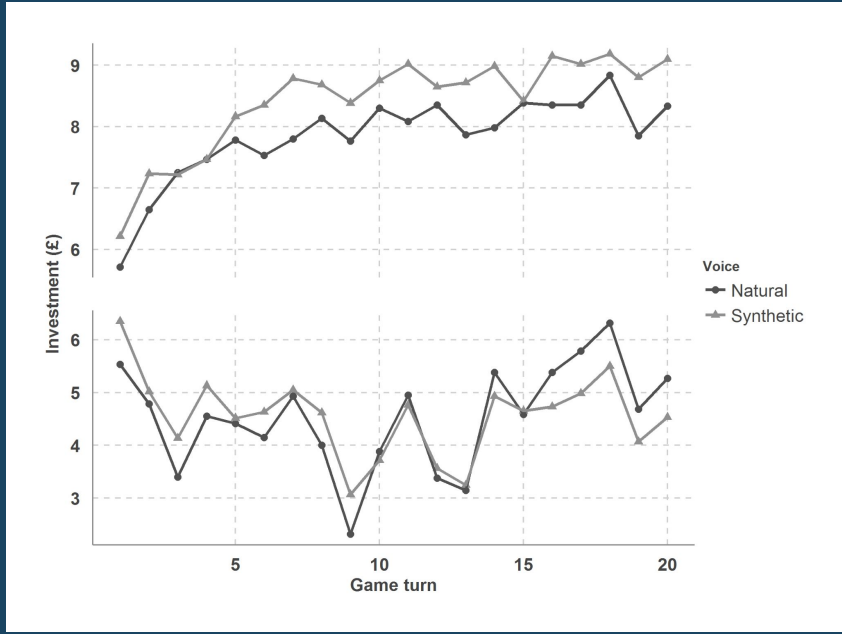
Experiment 4:

- 1 x natural SSBE voice, 1 x synthetic SSBE voice
- Trustworthy vs. untrustworthy robot
- 20 rounds
- N = 120 British participants

Torre, I., Goslin, J., White, L. & Zanatto, D. (2018). Trust in artificial voices: A ``congruency effect'' of first impressions and behavioural experience. In proc. *APA Technology, Mind,and Society*

Trust towards accented robots

- Higher investments to trustworthy robot
- Interaction behaviour x voice:
  - With trustworthy robot, higher investments to synthetic voice
  - With untrustworthy robot, higher investments to natural voice



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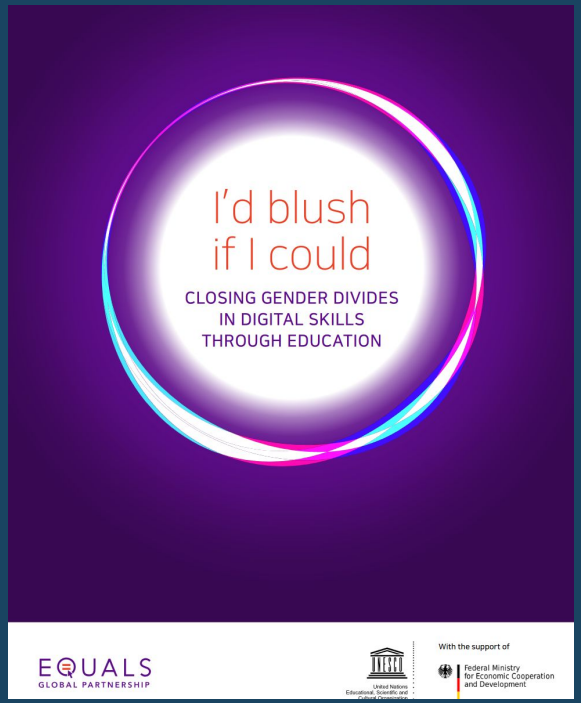
Overall results:

- Voice carries indexical information (accent, prosody, naturalness) that is used to decide on behaviour
- This decision is implicit and does not correlate to explicit ratings of trust
- Voice-based implicit judgments resist despite behavioural evidence
- Appeal to humanness when robot is behaving meanly
  - Human-likeness in one feature affords human-likeness in other features!

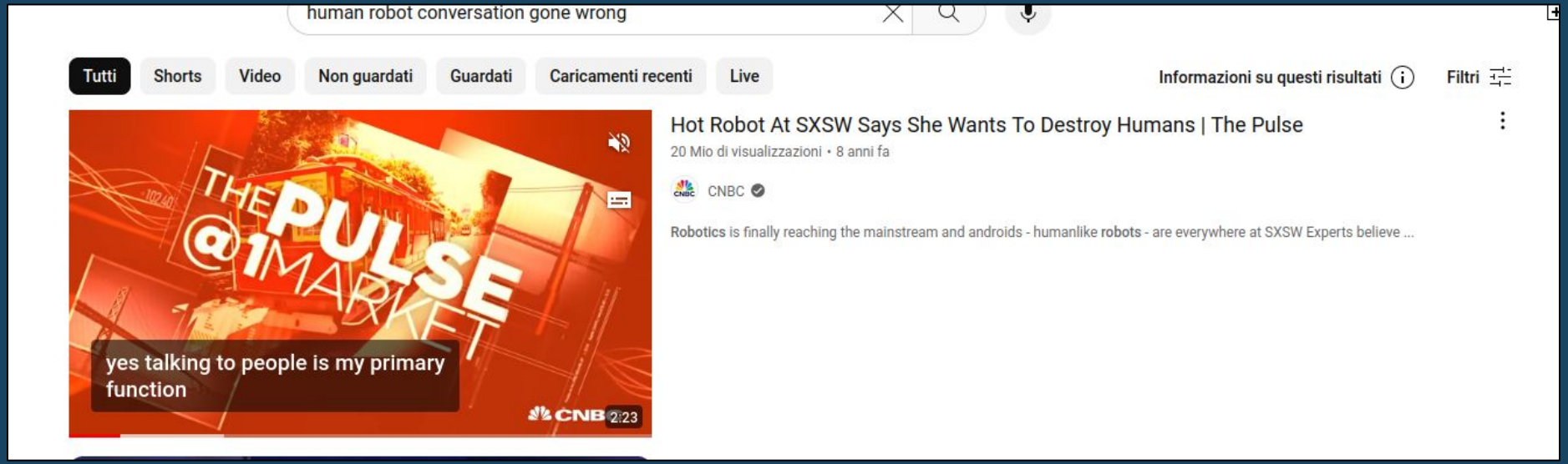
First impressions based on voice gender

First impressions based on voice gender



West, M., Kraut, R., & Ei Chew, H. (2019). I'd blush if I could: closing gender divides in digital skills through education.

First impressions based on voice gender



Artificial gender-ambiguous voices

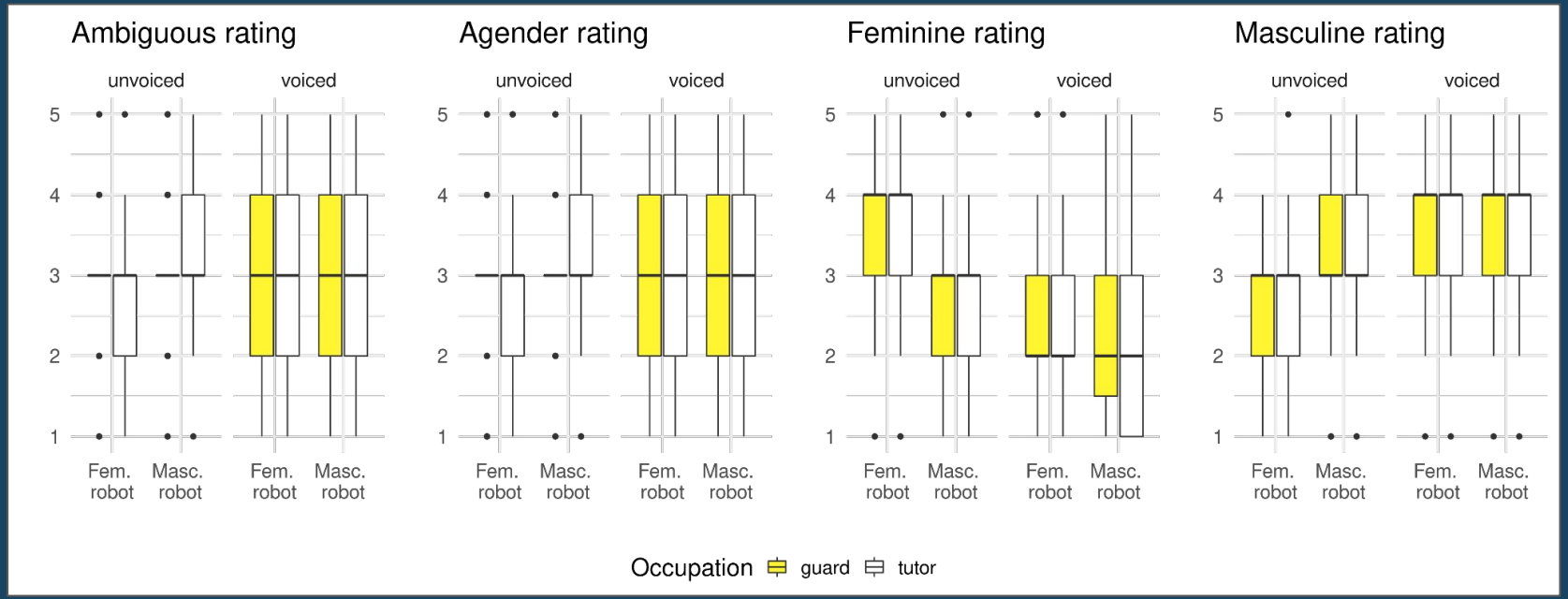



Székely, E., Gustafson, J., & Torre, I. (2023). Prosody-controllable gender-ambiguous speech synthesis: a tool for investigating implicit bias in speech perception. In *proc. INTERSPEECH*

Gendering of robots

Torre, I., Lagerstedt, E., Dennler, N., Seaborn, K., Leite, I., & Székely, É. (2023). Can a gender-ambiguous voice reduce gender stereotypes in human-robot interactions? In *proc. RO-MAN*

Gendering of robots



Torre, I., Lagerstedt, E., Dennler, N., Seaborn, K., Leite, I., & Székely, É. (2023). Can a gender-ambiguous voice reduce gender stereotypes in human-robot interactions? In *proc. RO-MAN*

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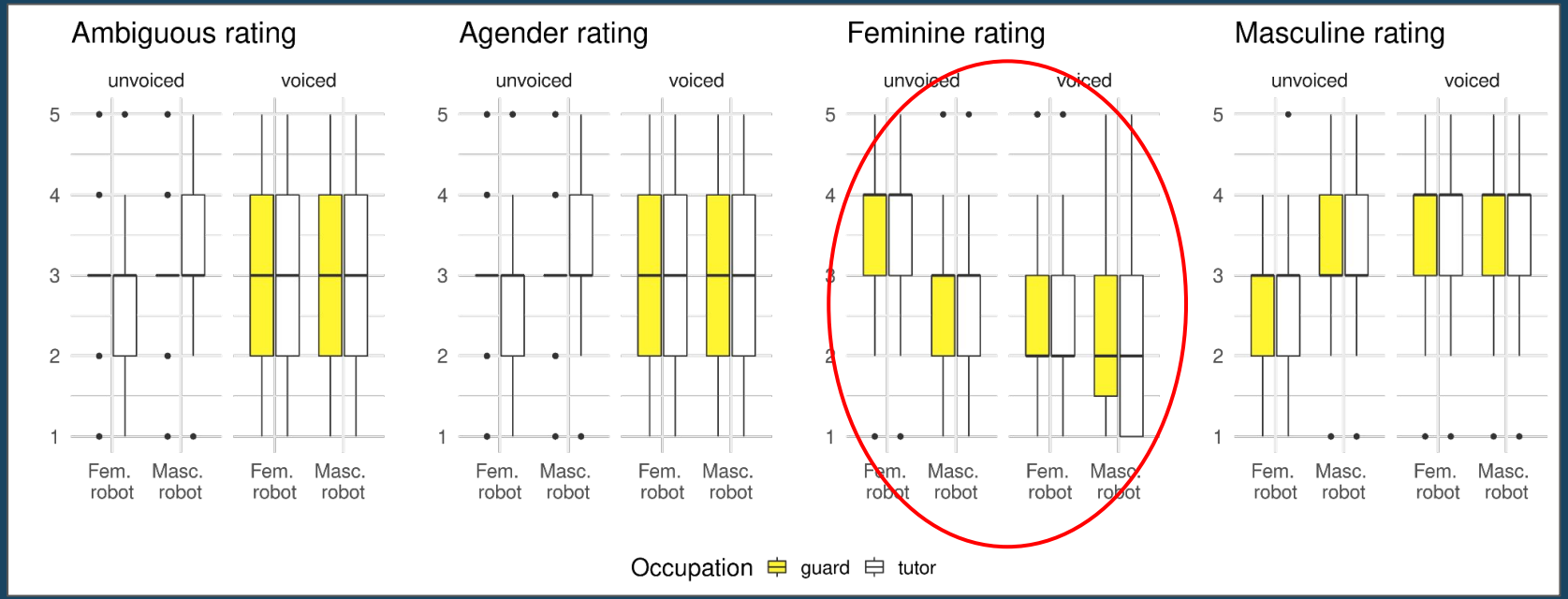

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First impressions of gender-ambiguous voices

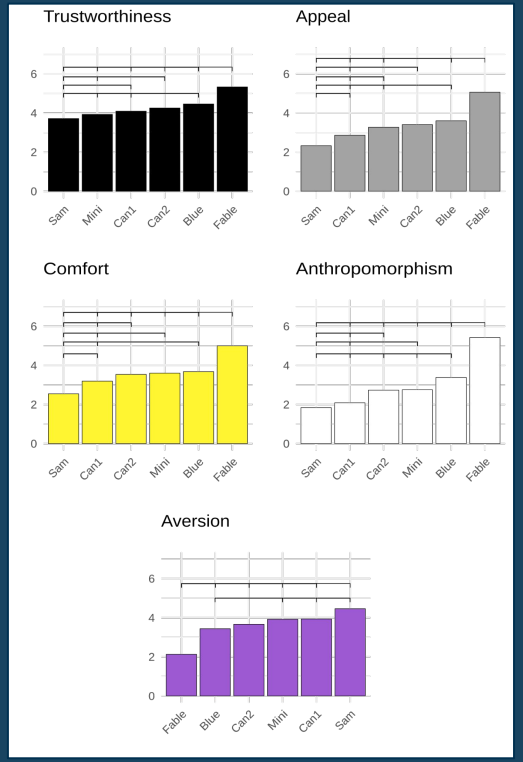
Online experiment:

- 6 x artificial gender-ambiguous voices
- Voice Experience Inventory (VOXI) questionnaire
  - Trustworthiness
  - Appeal
  - Comfort
  - Anthropomorphism
  - Aversion
- N = 222 British participants (74 = F, 74 = M, 74 = NB)

De Cet, M., Seaborn, K., Obaid, M., & Torre, I. (2025). Hearing Ambiguity: Exploring Beyond-Gender Impressions of Artificial Ambiguous Voices. In *Proc. of CUI*

First impressions of gender-ambiguous voices

- Higher overall ratings to Fable voice
- NB participants rated the voices lower on trust, anthropomorphism, and higher on aversion



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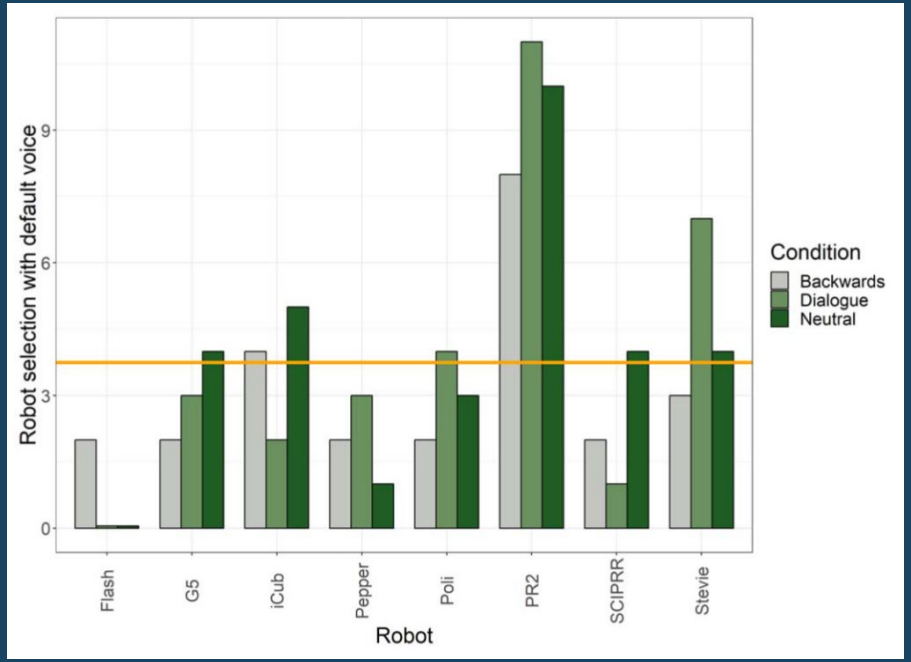
Overall results:

- Not all gender-ambiguous voices are created equal
- What is the purpose of these voices?
- Importance of including NB participants
  - (As we saw in a previous meta-review, they are usually not included in HRI / HCI studies)

Winkle, K., Lagerstedt, E., Torre, I., & Offenwanger, A. (2023). 15 years of (who) man robot interaction: Reviewing the h in human-robot interaction. *ACM Transactions on Human-Robot Interaction*, 12(3), 1-28.

Overall results:

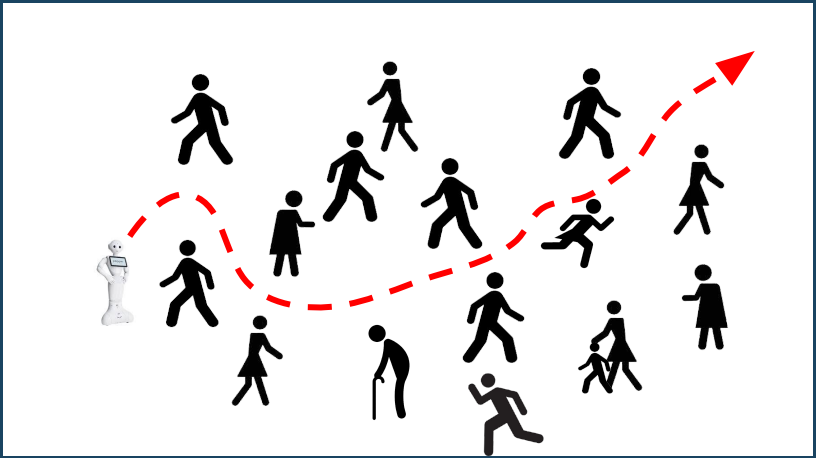
- Robot voice is important!
- Yet most robot developers choose voices out of convenience
- Current robots have voices that don't "fit"



McGinn, C., & Torre, I. (2019). Can you tell the robot by the voice? An exploratory study on the role of voice in the perception of robots. In *Proc. HRI*.

… Do robots even need voices??

Nonverbal communication for HRI



- Using sound to communicate a robot's actions, intentions and internal states in unintentional HRI
- People understand, from sound alone, whether the robot wants to turn left or right!

Orthmann, B., Leite, I., Bresin, R., & Torre, I. (2023). Sounding Robots: Design and Evaluation of Auditory Displays for Unintentional Human-robot Interaction. *ACM Transactions on Human-Robot Interaction, 12(4)*, 1-26.

In sum

- Robot voices elicit very nuanced perceptions
- Sometimes, these perceptions can be detrimental
- We need appropriate voices for appropriate robots for appropriate contexts
- And sometimes, we don’t need voices at all!

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ilariat@chalmers.se