# Social robots

## the ultimate test for AI and robotics

Tony Belpaeme

**IDLab – imec, Ghent University, Belgium**

Centre for Robotics and Neural Systems, Plymouth University, United Kingdom

GHENT UNIVERSITY · imec UNIVERSITY OF PLYMOUTH

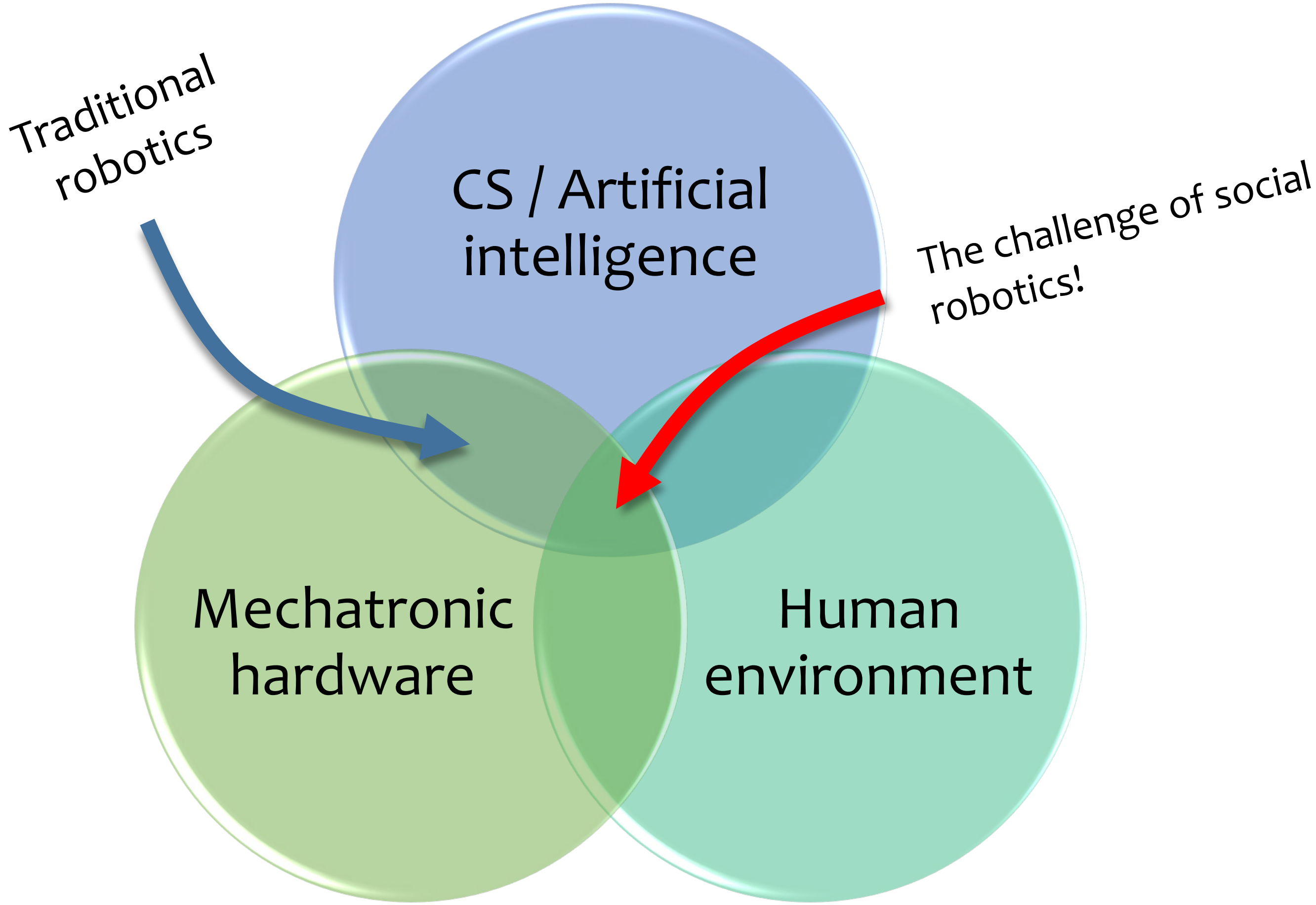
# The robot spectrum

Physical

Social

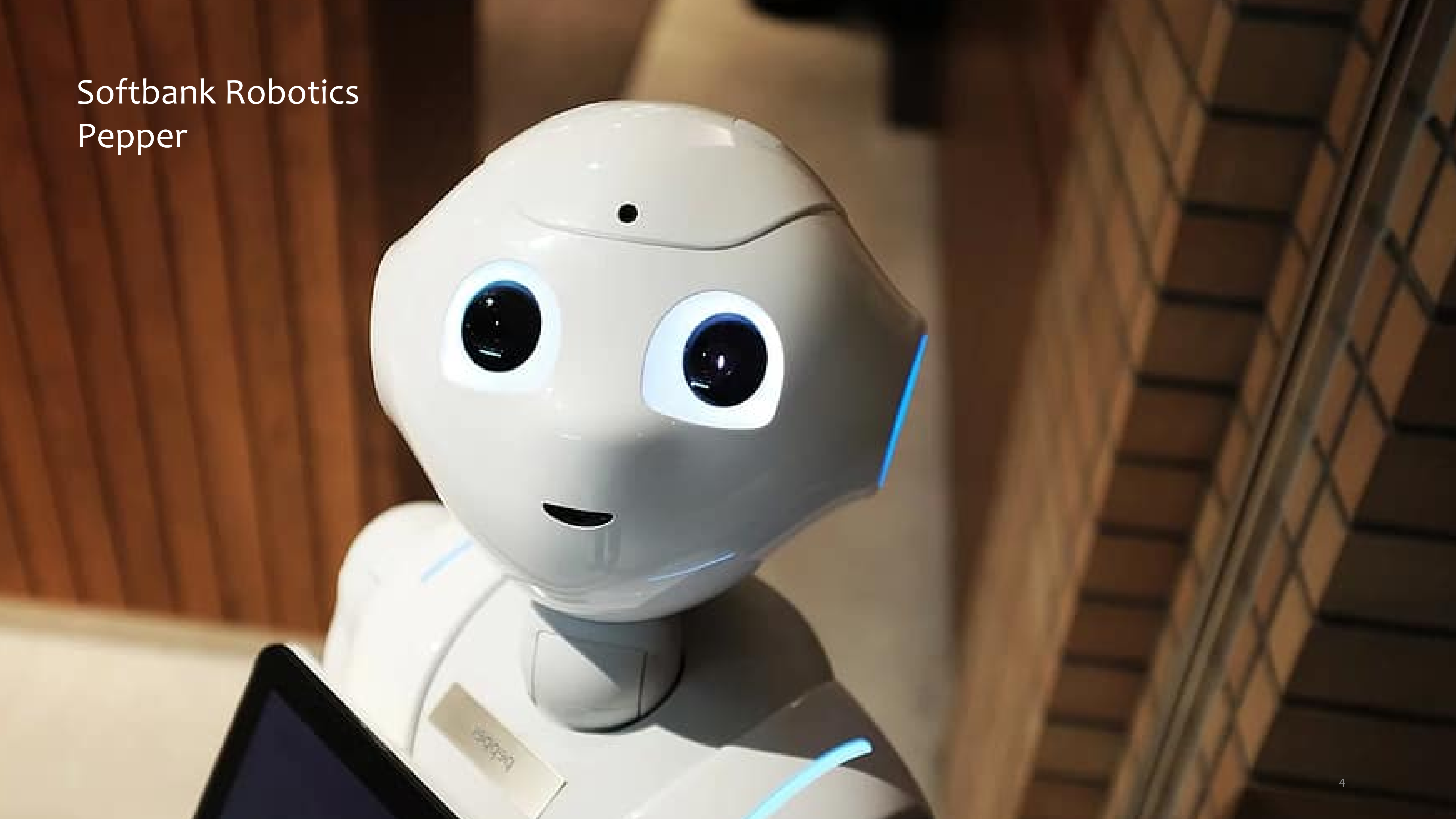
GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

# Positioning social robotics




GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

# Softbank Robotics
# Pepper




BlueFrog
Buddy


Anki
Vector

WooWee
KeepOn


Hanson Robotics
Sophia

# The psychology of building robots

# Tapping into our social brain

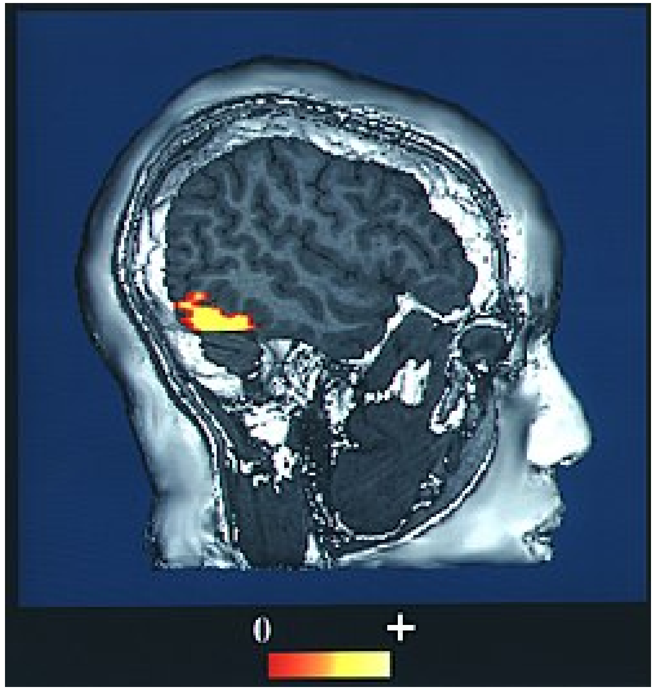
- We attribute human-like characteristics to artefacts, this effect is enhanced when the artefact is animated and responsive

- Social robots are designed to maximise this, and can induce **attention, compliance, conformity** …

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *The American Journal of Psychology*, 243-259.

# Pareidolia

- Perceiving human-like features in non-human stimuli.
- Evolutionary psychology explains pareidolia as a hyper response to face-like features.
- Better to respond to false positives than not respond to true positives.

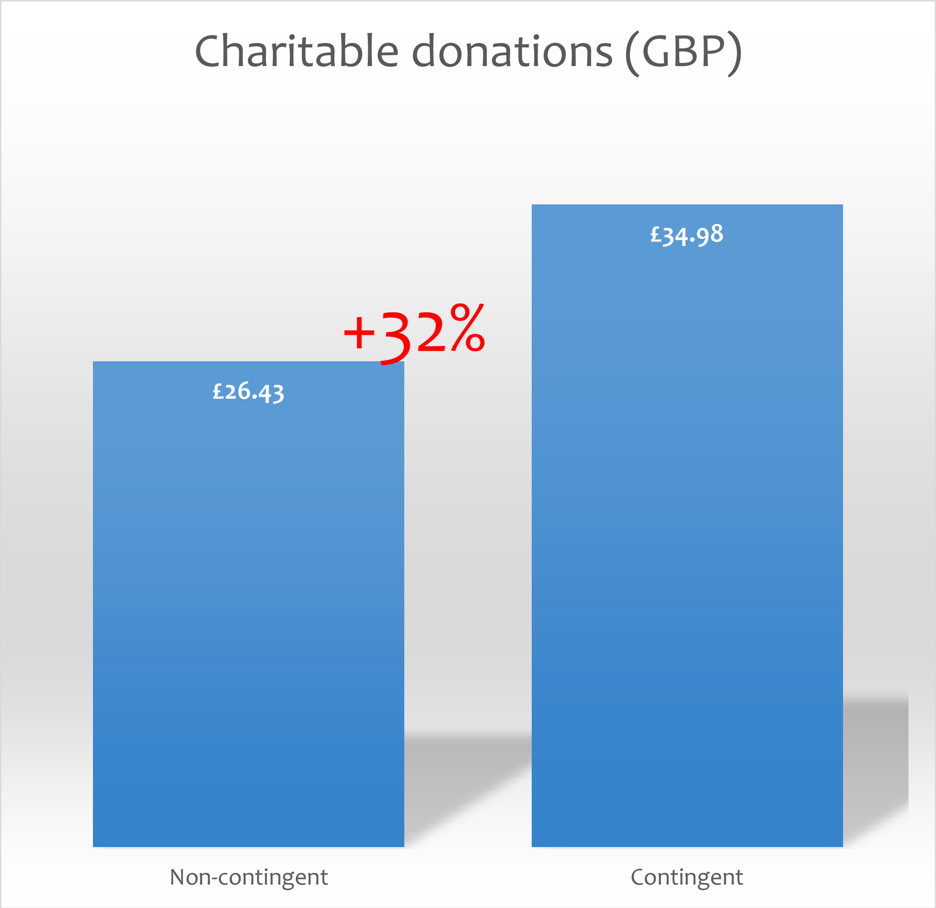



Fusiform Face Area responds to seeing faces and to pareidolia experiences

# Gaze behaviour

- What difference does appropriate gaze behaviour make?
- Two conditions
  1. Correctly timed eye contact
  2. Avoiding making eye contact
- How much money will the robot collect for charity?

(SociBot, EngineeredArts)




GHENT UNIVERSITY · imec
UNIVERSITY OF PLYMOUTH

# Robots as teachers

# Changes in the educational landscape

- Changing demographics
- Greater diversity in the class room
- Shrinking school budgets
- More pupils per class room
- A need for personalisation

# Robots for education

- Social robots can provide one-to-one tuition.
- They can achieve both cognitive and affective outcomes.
- Their physical and social presence makes robot tutors effective.

SCIENCE ROBOTICS | REVIEW

HUMAN-ROBOT INTERACTION

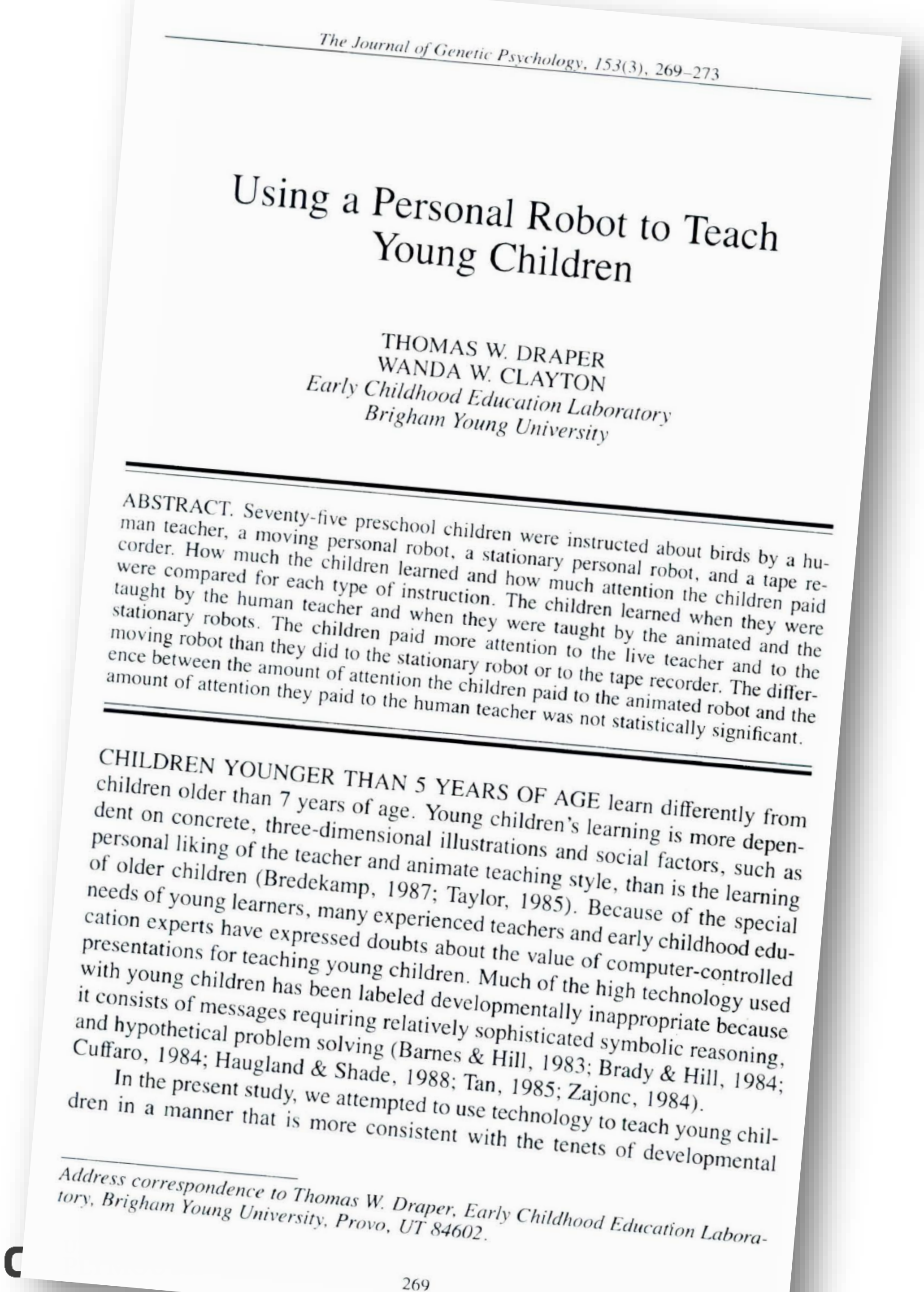
## Social robots for education: A review

**Tony Belpaeme[1,2]*, James Kennedy[2], Aditi Ramachandran[3], Brian Scassellati[3], Fumihide Tanaka[4]**



Social robots can be used in education as tutors or peer learners. They have been shown to be effective at increasing cognitive and affective outcomes and have achieved outcomes similar to those of human tutoring on restricted tasks. This is largely because of their physical presence, which traditional learning technologies lack. We review the potential of social robots in education, discuss the technical challenges, and consider how the robot's appearance and behavior affect learning outcomes.

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for education: A review. *Science Robotics*, 3(21), eaat5954.


The Journal of Genetic Psychology, 153(3), 269–273

# Using a Personal Robot to Teach Young Children

THOMAS W. DRAPER
WANDA W. CLAYTON
*Early Childhood Education Laboratory*
*Brigham Young University*

ABSTRACT. Seventy-five preschool children were instructed about birds by a human teacher, a moving personal robot, a stationary personal robot, and a tape recorder. How much the children learned and how much attention the children paid were compared for each type of instruction. The children learned when they were taught by the human teacher and when they were taught by the animated and the stationary robots. The children paid more attention to the live teacher and to the moving robot than they did to the stationary robot or to the tape recorder. The difference between the amount of attention the children paid to the animated robot and the amount of attention they paid to the human teacher was not statistically significant.

CHILDREN YOUNGER THAN 5 YEARS OF AGE learn differently from children older than 7 years of age. Young children's learning is more dependent on concrete, three-dimensional illustrations and social factors, such as personal liking of the teacher and animate teaching style, than is the learning of older children (Bredekamp, 1987; Taylor, 1985). Because of the special needs of young learners, many experienced teachers and early childhood education experts have expressed doubts about the value of computer-controlled presentations for teaching young children. Much of the high technology used with young children has been labeled developmentally inappropriate because it consists of messages requiring relatively sophisticated symbolic reasoning and hypothetical problem solving (Barnes & Hill, 1983; Brady & Hill, 1984; Cuffaro, 1984; Haugland & Shade, 1988; Tan, 1985; Zajonc, 1984).

In the present study, we attempted to use technology to teach young children in a manner that is more consistent with the tenets of developmental

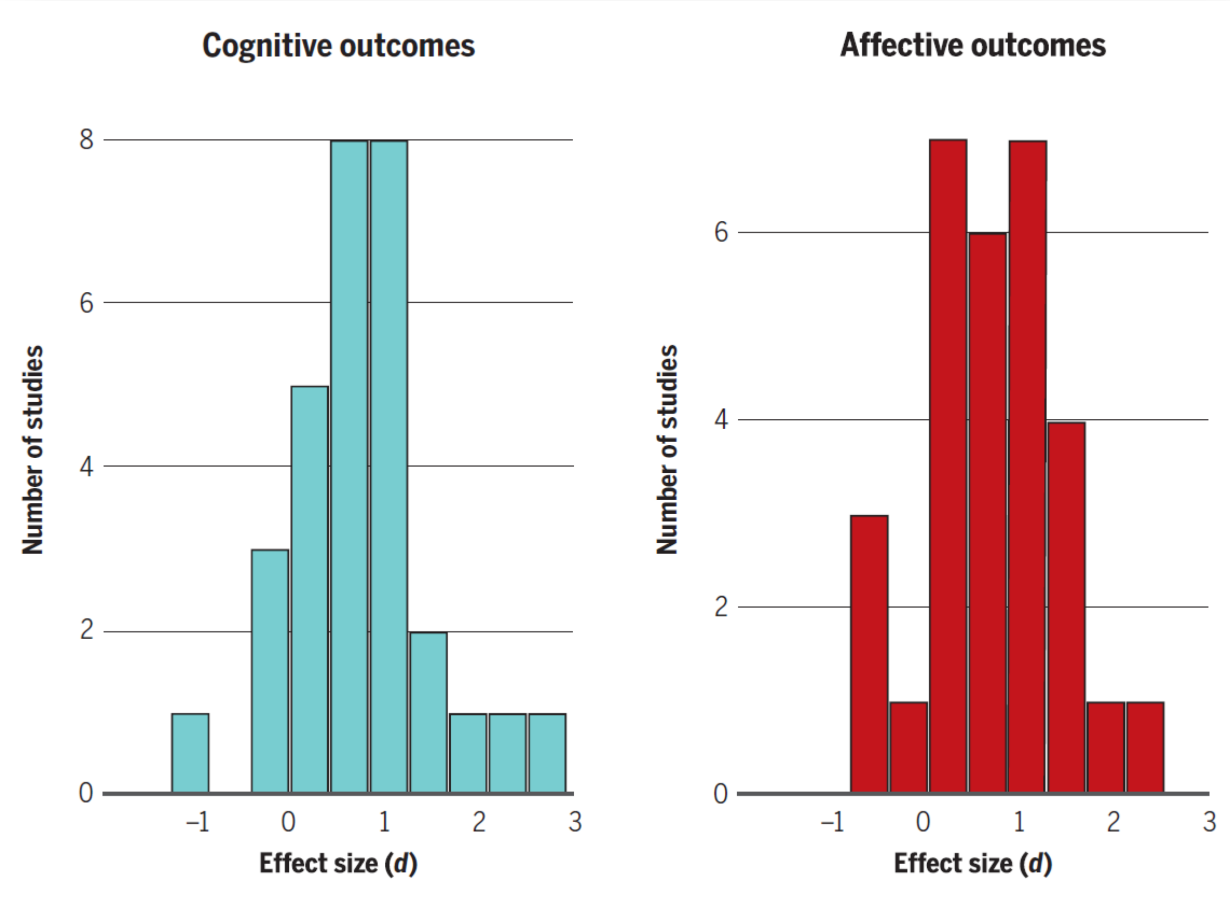
*Address correspondence to Thomas W. Draper, Early Childhood Education Laboratory, Brigham Young University, Provo, UT 84602.*



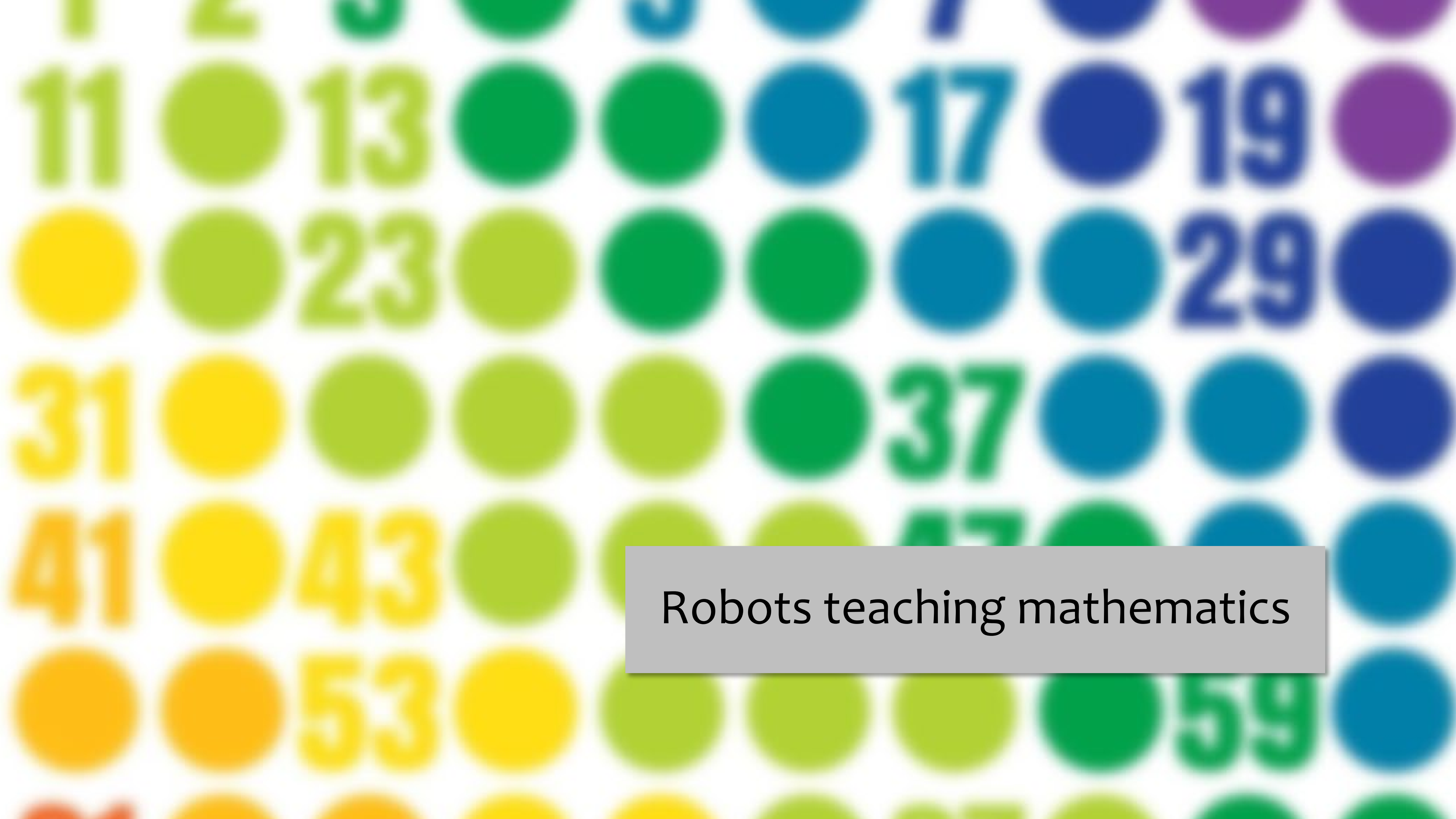

# Effect sizes of outcomes

- Effect size Cohen's $d = \frac{\overline{x_2} - \overline{x_1}}{\sigma_1}$
  - 0.2 = small
  - 0.5 = medium
  - 0.8 = large

- 37 results compared a robot to alternative tech or human tutoring.
- **Cognitive *d* = 0.70**
- **Affective *d* = 0.59**
- Human tutor achieve cognitive outcomes of d = 0.79
- Positive affective outcomes do not mean positive cognitive outcomes, or vice versa.



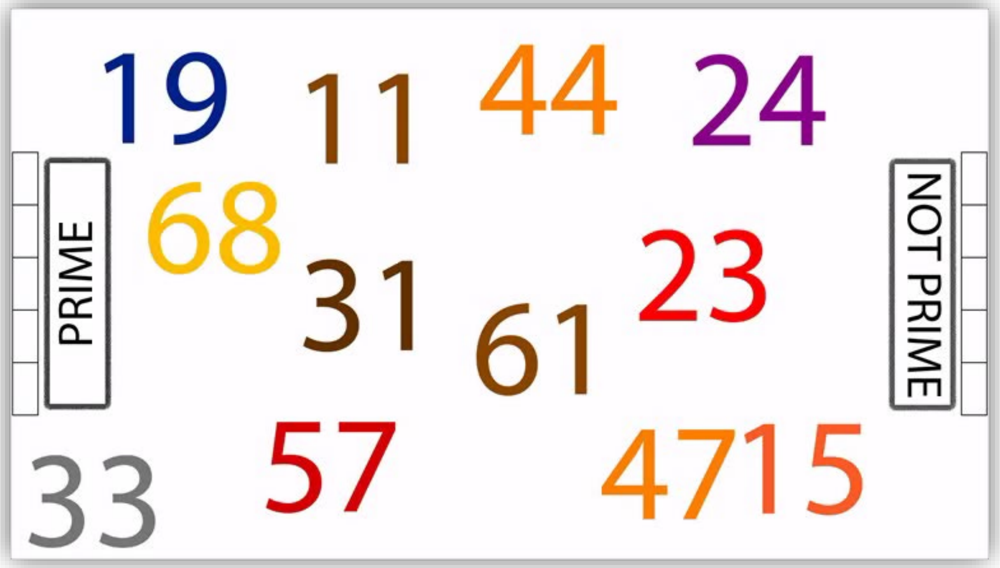

GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH



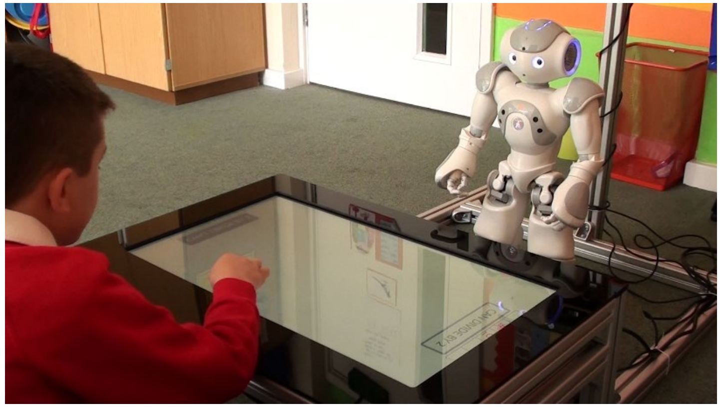

# Robots teaching mathematics

# Methodology - Sorting prime numbers

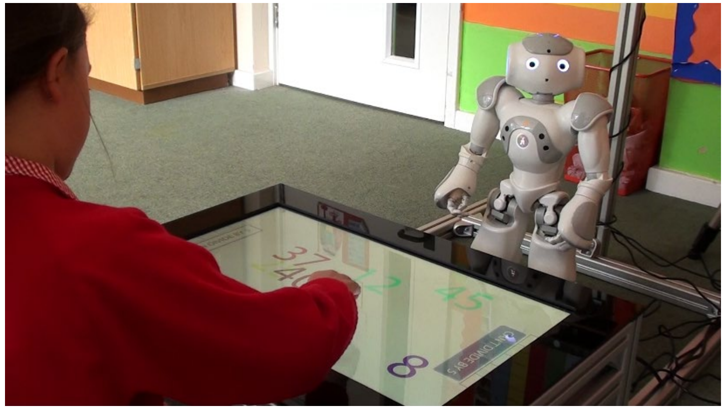
- Separating prime numbers from non-primes
- Material and structure devised with help from teachers
- Learning outcome: concept of prime number/Sieve of Eratosthenes




GHENT UNIVERSITY · imec UNIVERSITY OF PLYMOUTH



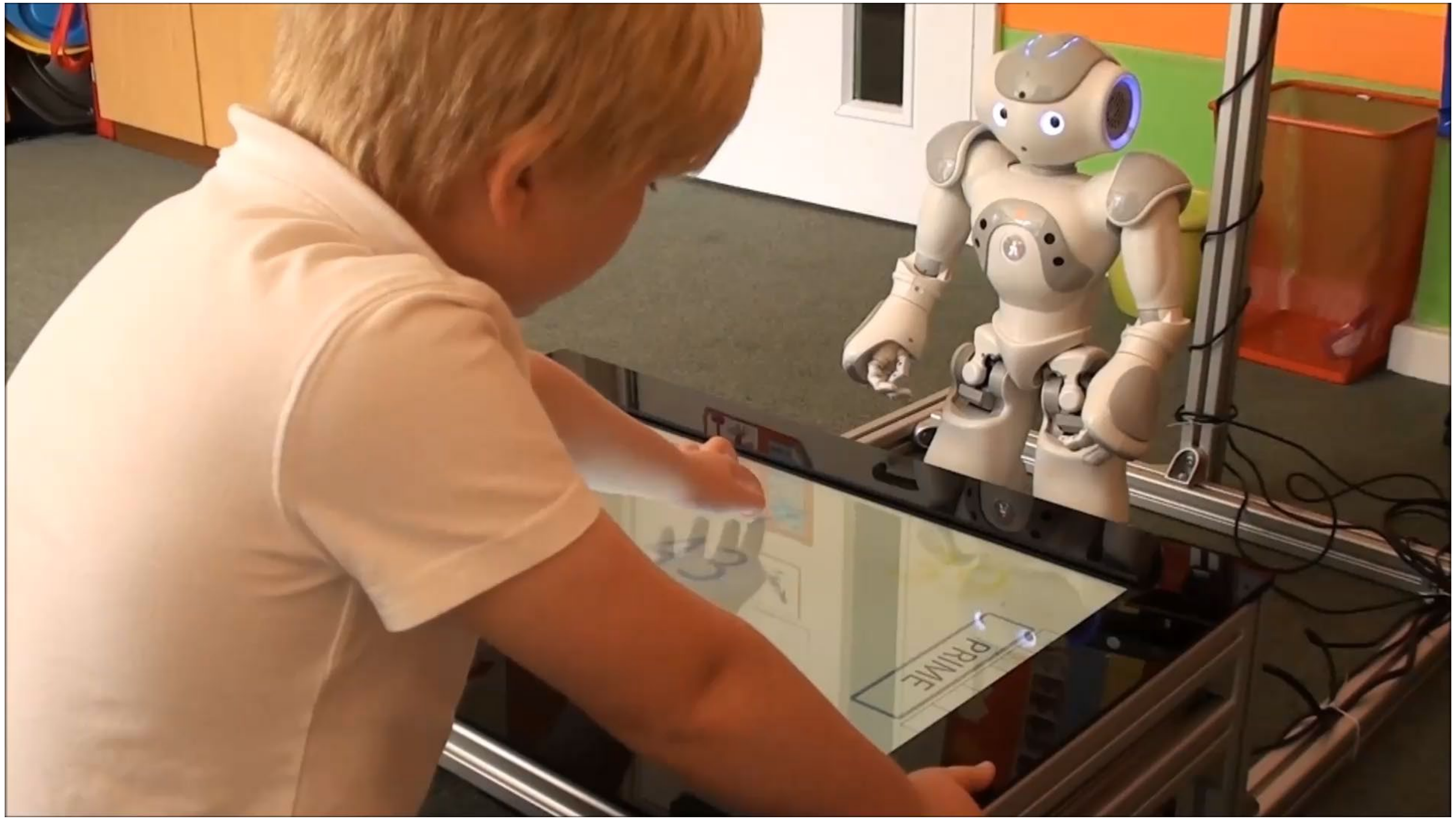
Social, personalised robot (*n*=12)



Non-social, non-personalised robot (*n*=11)

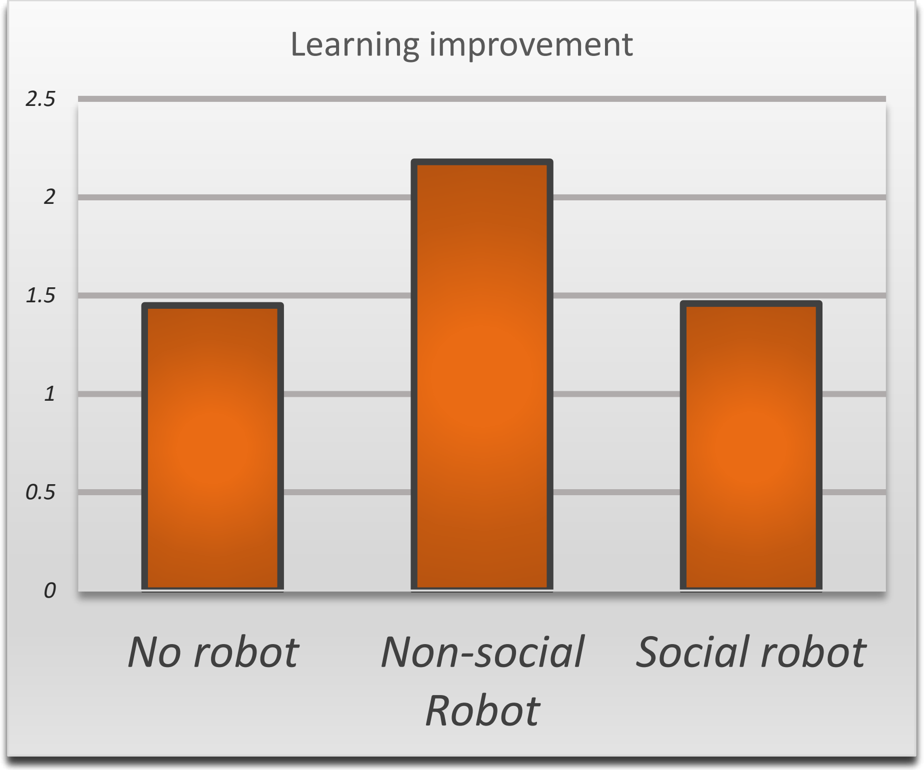
Inversion of social and personalisation behaviour

# Social robot



# Non-social robot

# Results




| Condition | Ave. Score Pre [95% CI] | Ave. score Post [95% CI] |
|---|---|---|
| Asocial, non-personalised robot (asocial robot) | 6.27 [5.00, 7.54] | 8.45 [6.84, 10.07] |
| Social, personalised robot (social robot) | 5.83 [4.54, 7.13] | 7.17 [5.50, 8.84] |

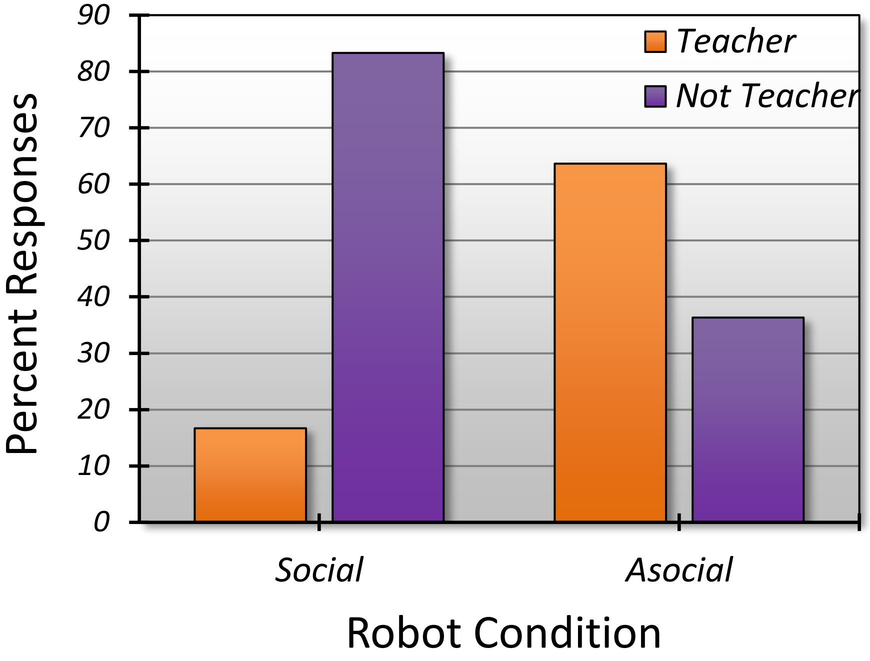
*Non-social robot:* $t(10)=2.597$, $p = 0.027$ *

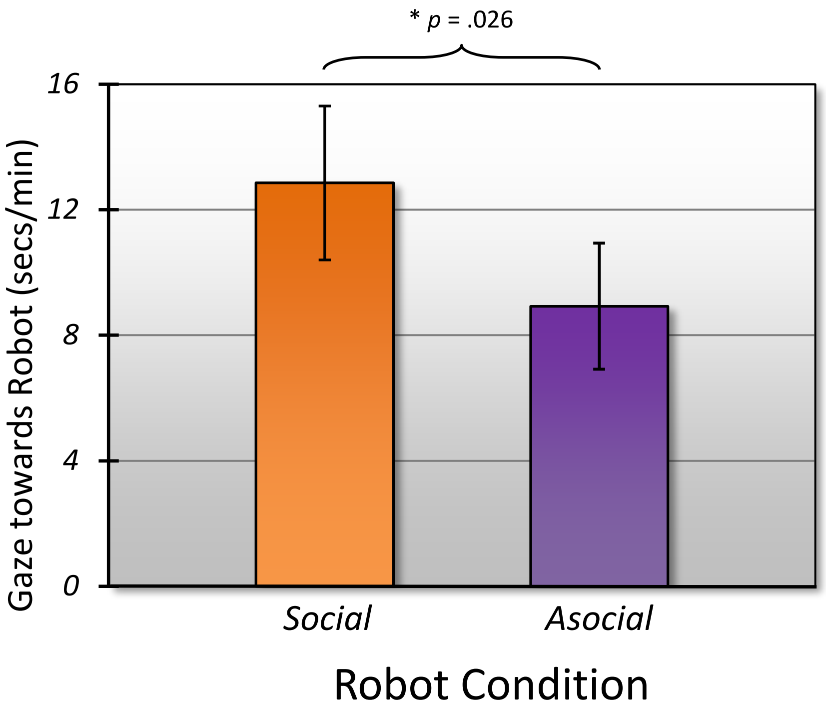
*Social robot:* $t(11)=1.627$, $p = 0.132$

GHENT UNIVERSITY · imec UNIVERSITY OF PLYMOUTH

# Why does a social robot not trump a non-social robot?

- Varying motivation, distraction, expectations?






Kennedy, J., Baxter, P., & Belpaeme, T. (2015, March). The robot who tried too hard: Social behaviour of a robot tutor can negatively affect child learning. In *2015 10th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 67-74). IEEE.

# Robots for Language Learning

# Learning languages

- Current classroom setup is ill-suited for language tuition
  - “Broadcast mode” of education doesn’t fit how people acquire first and second languages (or most other knowledge for that matter).
  - Social interaction is important for language acquisition.

- Children are very receptive to learning languages
  - Critical Period Hypothesis: learn a language before puberty.
  - Performance tails off after puberty (but contested).

- Migrant children benefit from personalised language tutoring
  - With potential long-term return on investment.

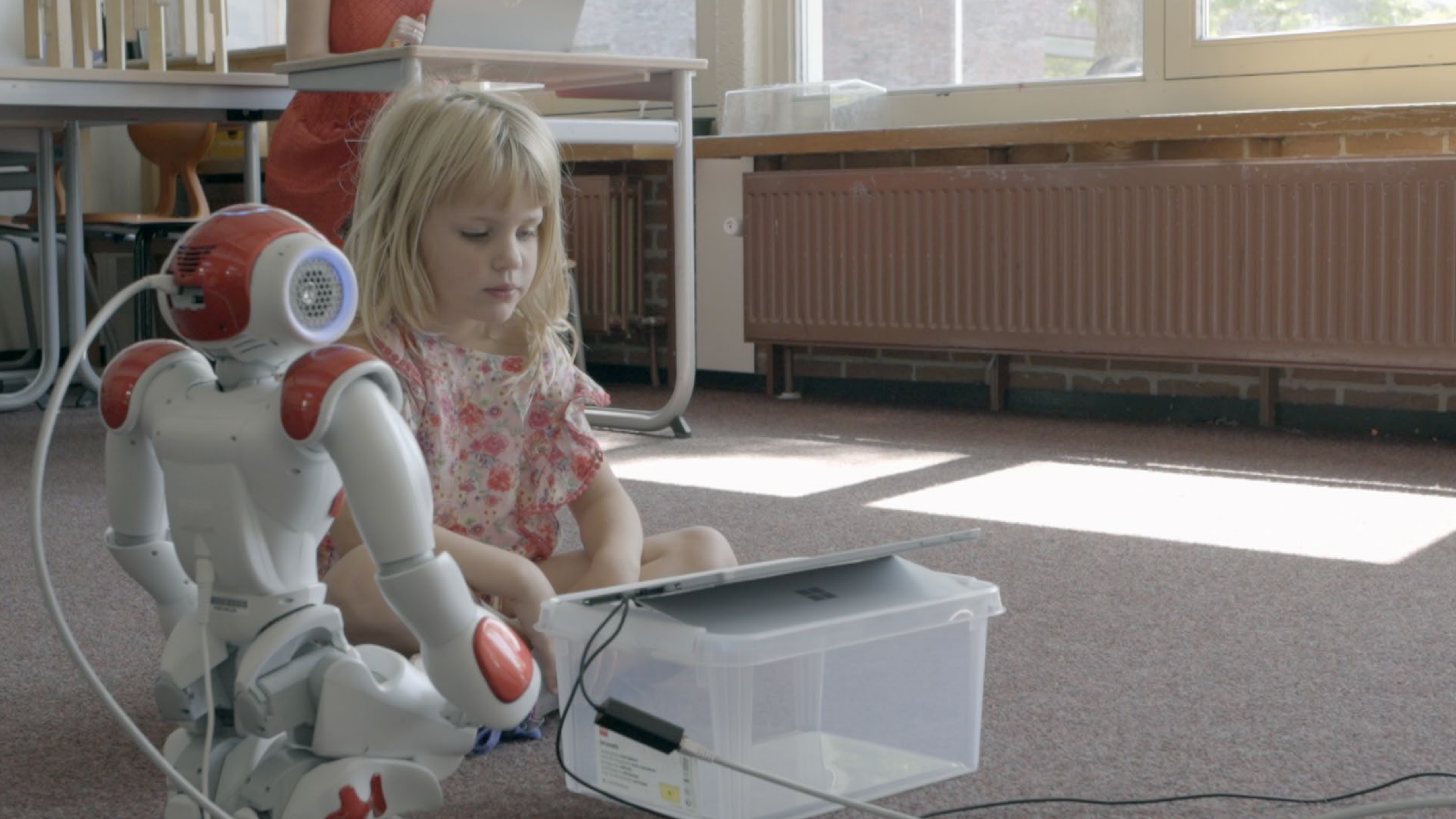
Kuhl, P. K. (2010). Brain mechanisms in early language acquisition. Neuron, 67(5), 713-727.
Snow, C. E., & Hoefnagel-Höhle, M. (1978). The critical period for language acquisition: Evidence from second language learning. *Child development*, 1114-1128.

# Possibly the greatest challenge of all

- Vocabulary learning works, beyond that things become very complicated.
- Conflicting age demands: start as early as possible, but interactions with the robot need older age due to their structure.
- Technical challenges prevent a dyadic conversation with the robot.
  - Speech recognition for children
  - Dialogue
  - Natural language processing in L1 and target language
  - Social signal processing



van den Berghe, R., Verhagen, J., Oudgenoeg-Paz, O., van der Ven, S., & Leseman, P. (2018). Social Robots for Language Learning: A Review. *Review of Educational Research*, 0034654318821286.



Video available at www.l2tor.eu

L2TOR is a European project that investigates how preschool children can learn a second language from a social robot.


Robots for therapy

# Autism Spectrum Disorders

- Significant social, communication and behavioural challenges.
- People with ASD may communicate, interact, behave, and learn in ways that are different from most other people.
- In the US, 1 in 68 children has been identified with ASD.
- ASD is about 4.5 times more common among boys.


GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

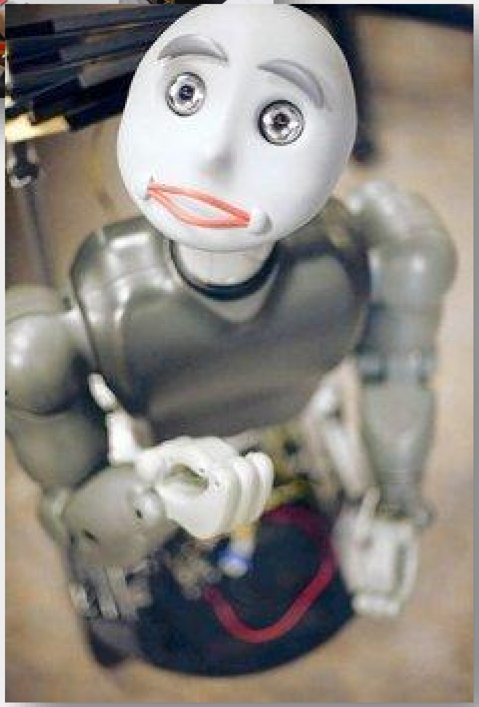
# Therapy

- Applied Behavioural Analysis (ABA)/Cognitive Behavioural Therapy are the most used and recognised ASD therapies

- Practising social skills, such as joint attention, imitation, turn taking

- Stimulus → behaviour → reward

# Robots and ASD



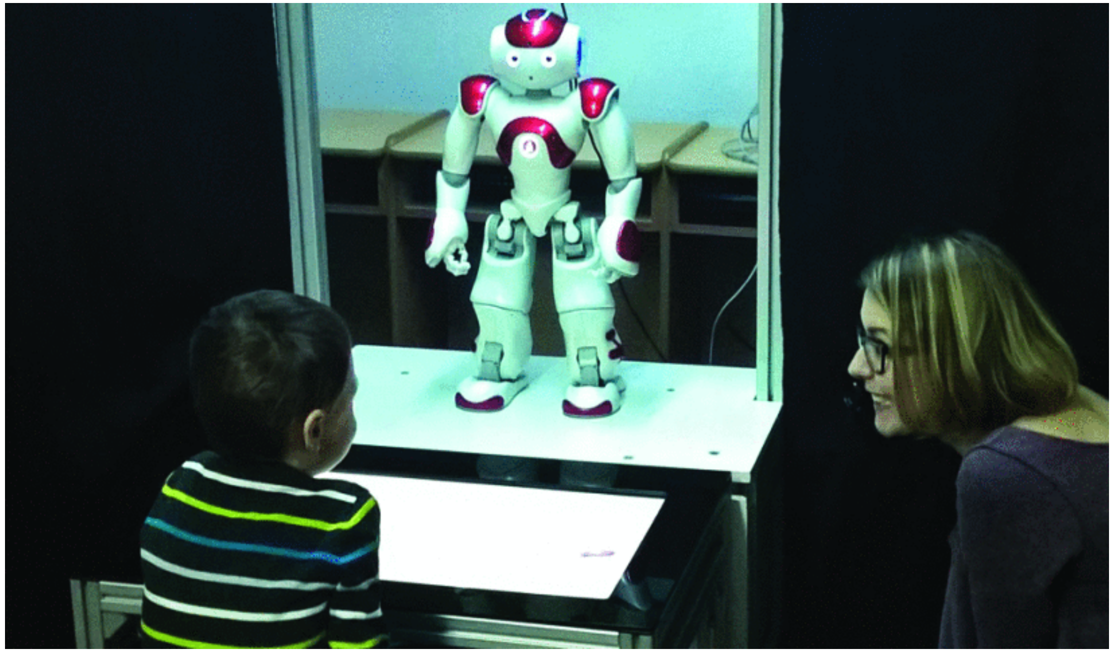
Dautenhahn, Mataric, Scassellati, Belpaeme/Thill/
Vanderborght, Kozima, …

# Robot therapy

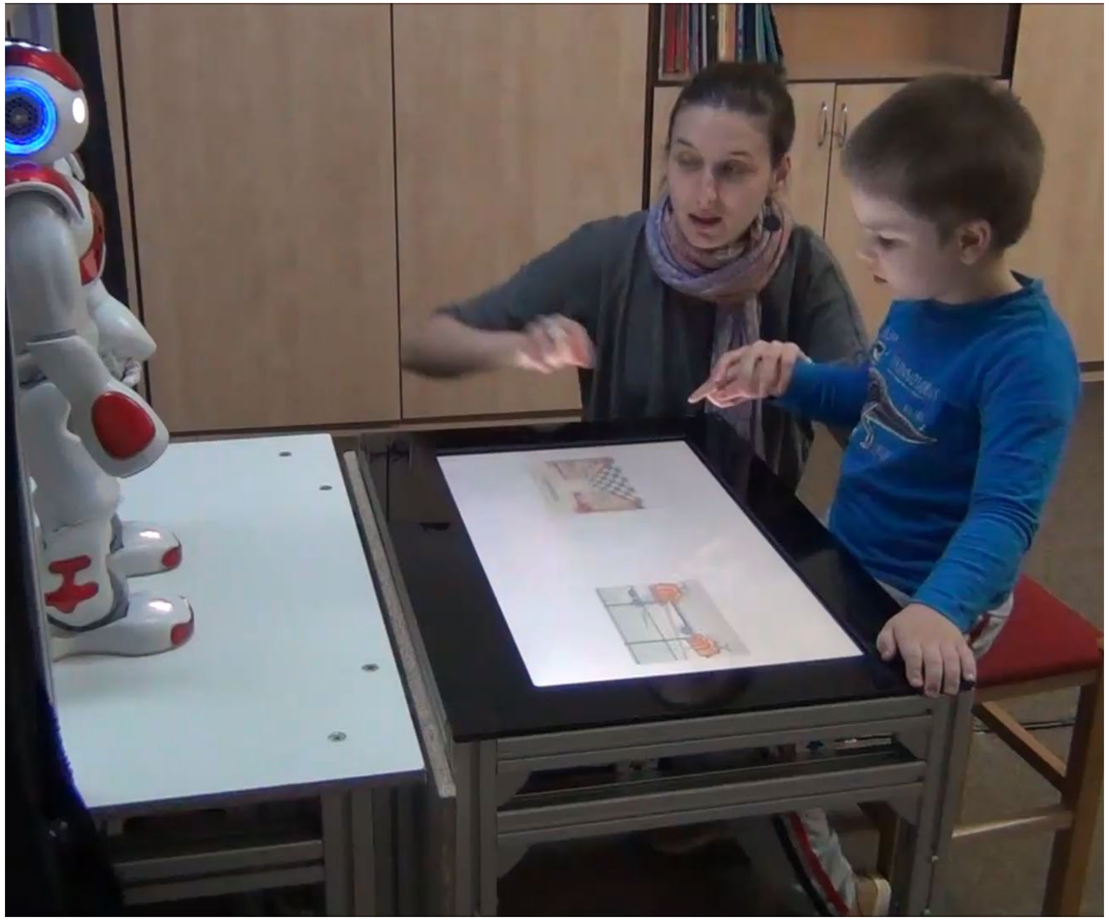
- Lots of interest in robots, based on initial evidence that children with ASD find robots appealing.
- But weak evidence on their efficacy, with all studies being qualitative reports or use cases on a limited number of children.
- The DREAM project set out to remedy this (www.dream2020.eu)

# DREAM project

- Using a robot to offer CBT.
- The robot is semi-autonomous, instead of teleoperated.
- The robot is a mediating device for social skills, we want learned social skills to transfer to human interaction.

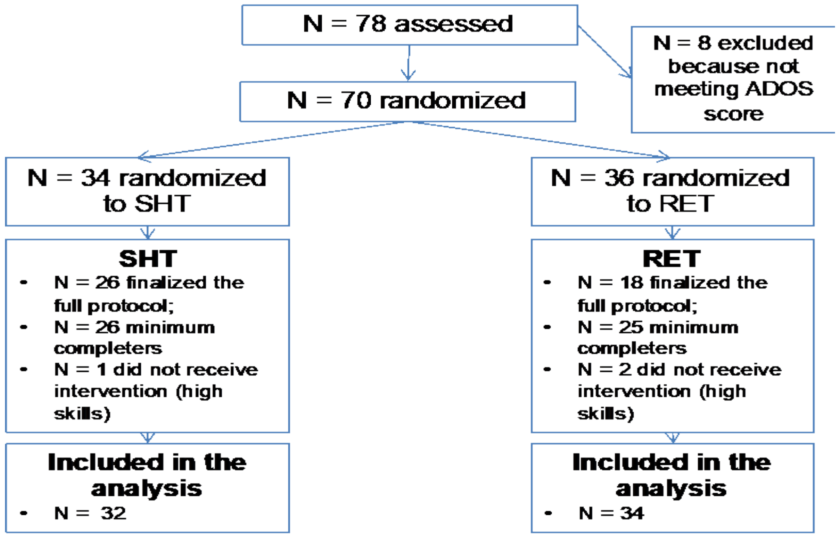


# Imitation, joint-attention, and turn-taking



# Randomised Control Trial

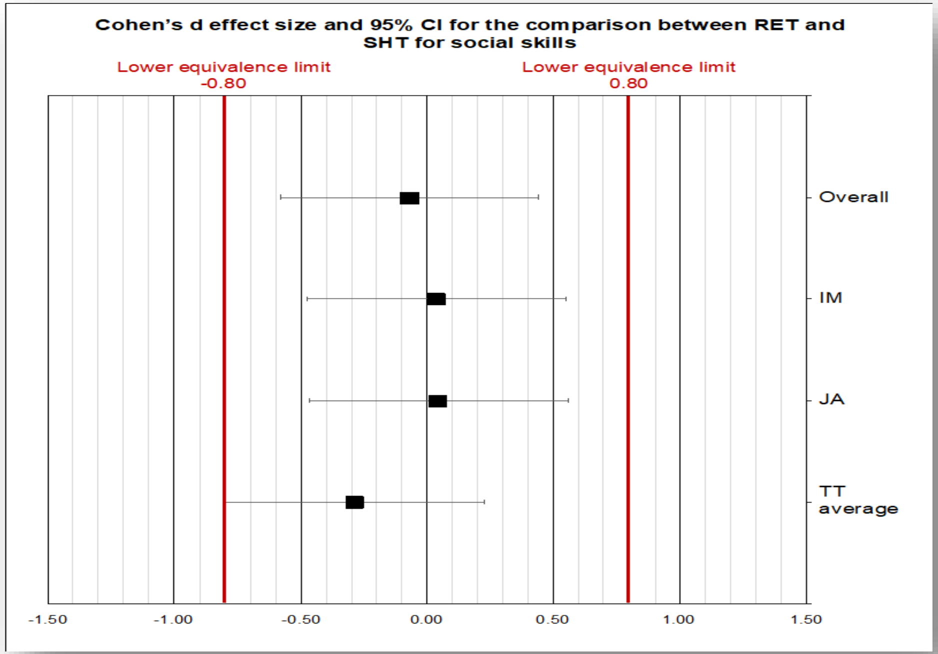
- 70 children (11 females; mean age 4.7 years), 12 sessions per child.
- Diagnosed using the Autism Diagnostic Observation Schedule (ADOS) assessment and Social Communication Questionnaire (SCQ).
- Compared Robot Enhanced Therapy (RET) against standard human therapy (SHT)



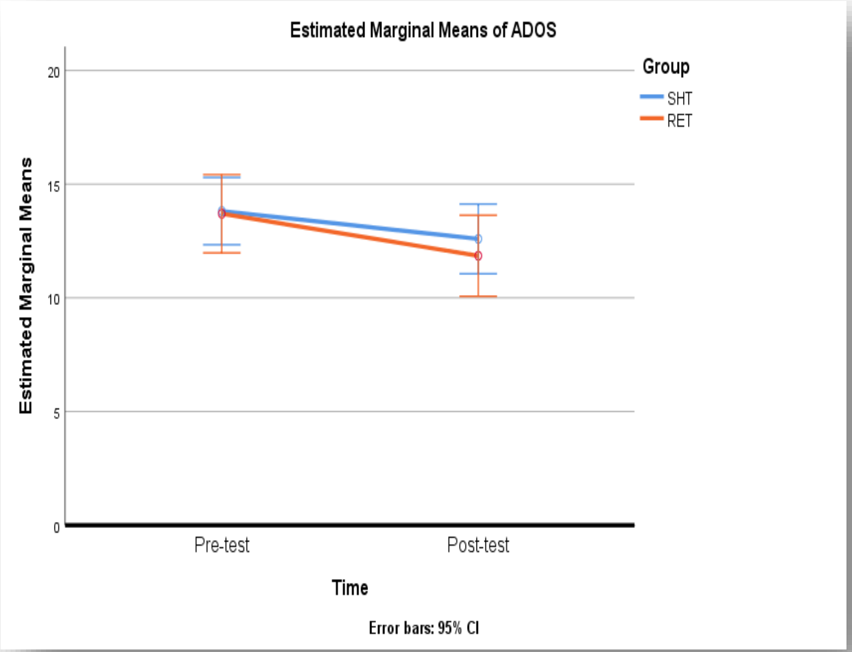

GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

# Results

- **Results indicate that robot therapy is equivalent to standard therapy**




Social skills




ADOS score

GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

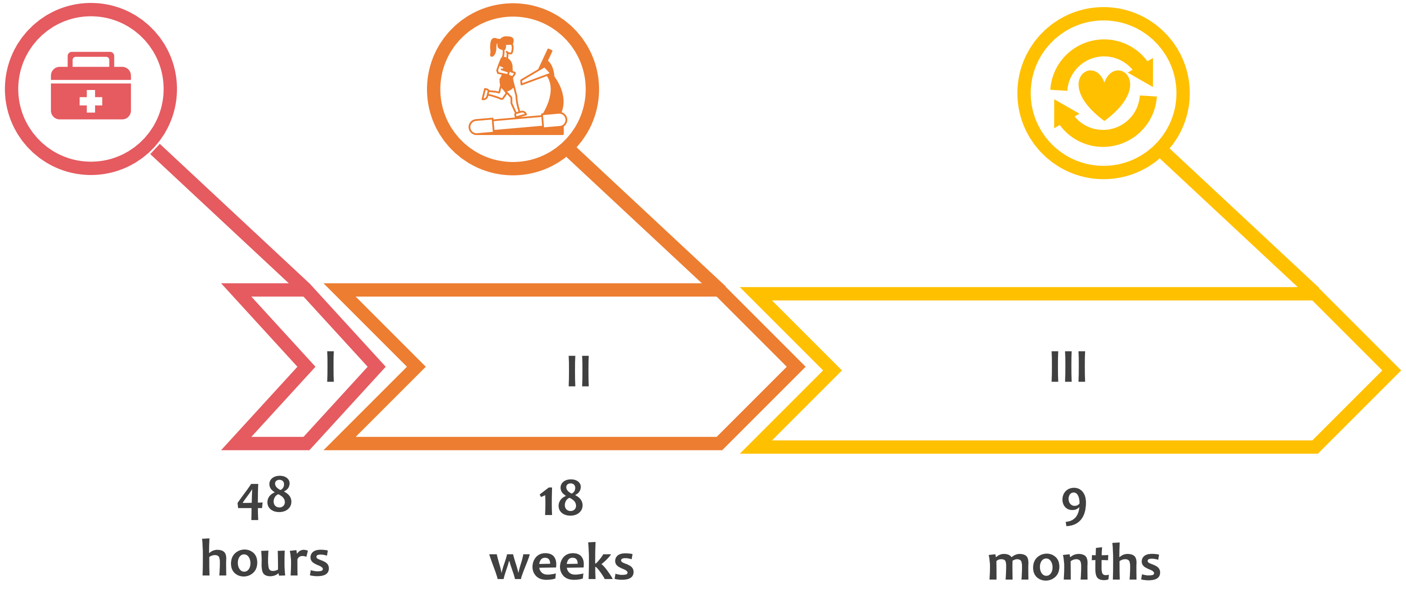
# Cardiovascular diseases and rehabilitation

- CVDs are the number 1 cause of death globally: more people die annually from CVDs than from any other cause.
- 17.9 million people died from CVDs in 2016, representing **31% of all global deaths**

* https://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

# Cardiovascular diseases and rehabilitation

*Challenging to provide continuous monitoring*




*Lack of motivation and dropouts*

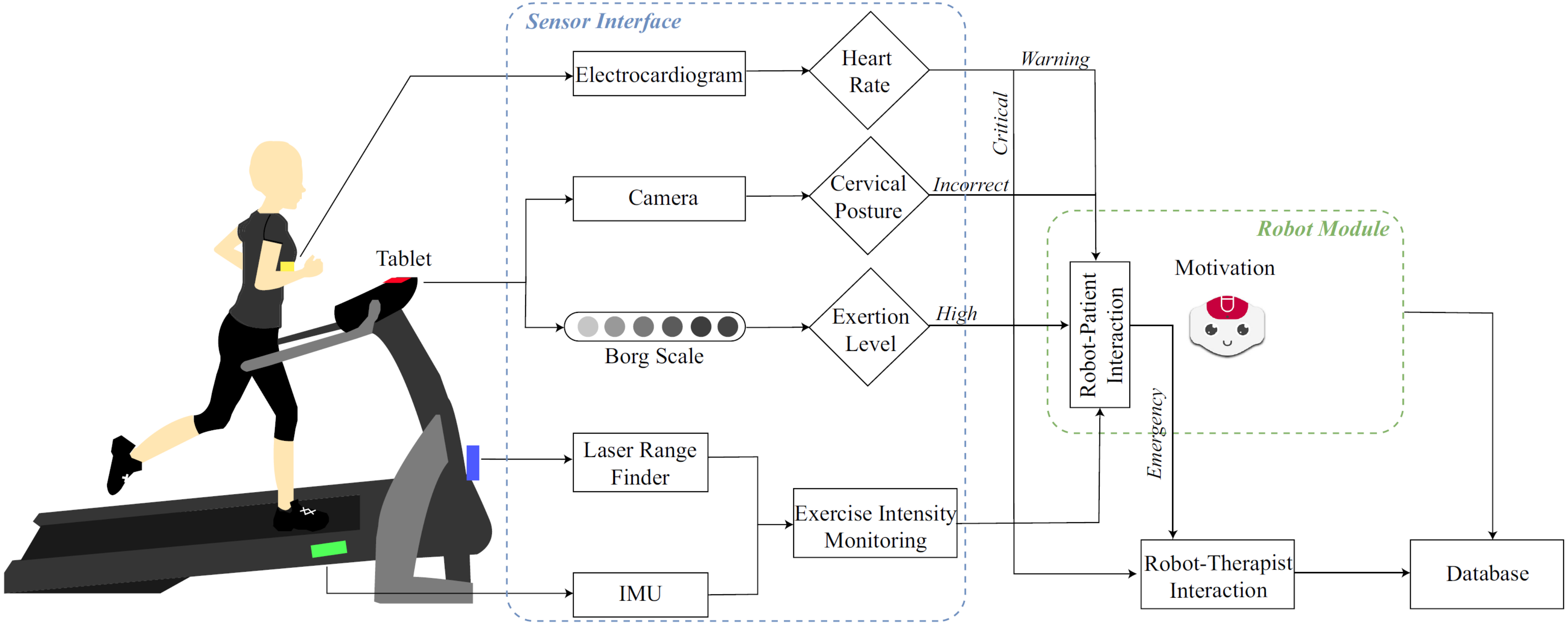
# Personalised socially assistive robot


Lara et al. (2017a,b); Casas et al. (2018a,b,c, 2019); Irfan et al. (2020b)

*In collaboration with Colombian School of Engineering Julio Garavito and Fundación Cardioinfantil-Instituto de Cardiología*

GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

# Robots in healthcare




GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

# Robots in healthcare


GHENT UNIVERSITY · imec UNIVERSITY OF PLYMOUTH

Céspedes, N., Irfan, B., Senft, E., Cifuentes, C. A., Gutierrez, L. F., Rincon-Roncancio, M., ... & Múnera, M. (2021). A Socially Assistive Robot for Long-Term Cardiac Rehabilitation in the Real World. *Frontiers in Neurorobotics*, *15*.

# The biggest challenge for AI?

# Wizard-of-Oz

- Wizard of Oz approaches in HRI research still amount for **50% of all studies.**

- Useful for a quick and cheap study or as a stub for underperforming technology.

- But the goal is **autonomous human-robot interaction.**

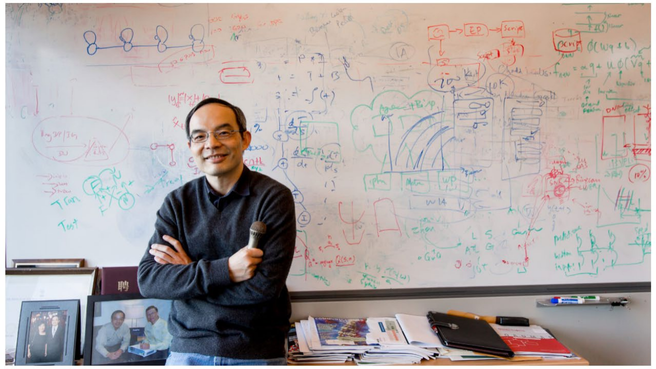
# Speech recognition: super human?

## Microsoft claims new speech recognition record, achieving a super-human 5.1% error rate

BY TODD BISHOP on August 20, 2017 at 7:44 pm

5 Comments | Share 820 | Tweet | Share | Reddit | Email





Xuedong Huang, a Microsoft Technical Fellow in AI and Research, leads Microsoft's Speech and Language Group. (Microsoft Photo)



## IBM speech recognition is on the verge of super-human accuracy

Chris Weller

Mar. 9, 2017, 4:58 PM 1,494

FACEBOOK | LINKEDIN | TWITTER | EMAIL | PRINT

In the world of speech recognition software, 5.1% is kind of a magic number.

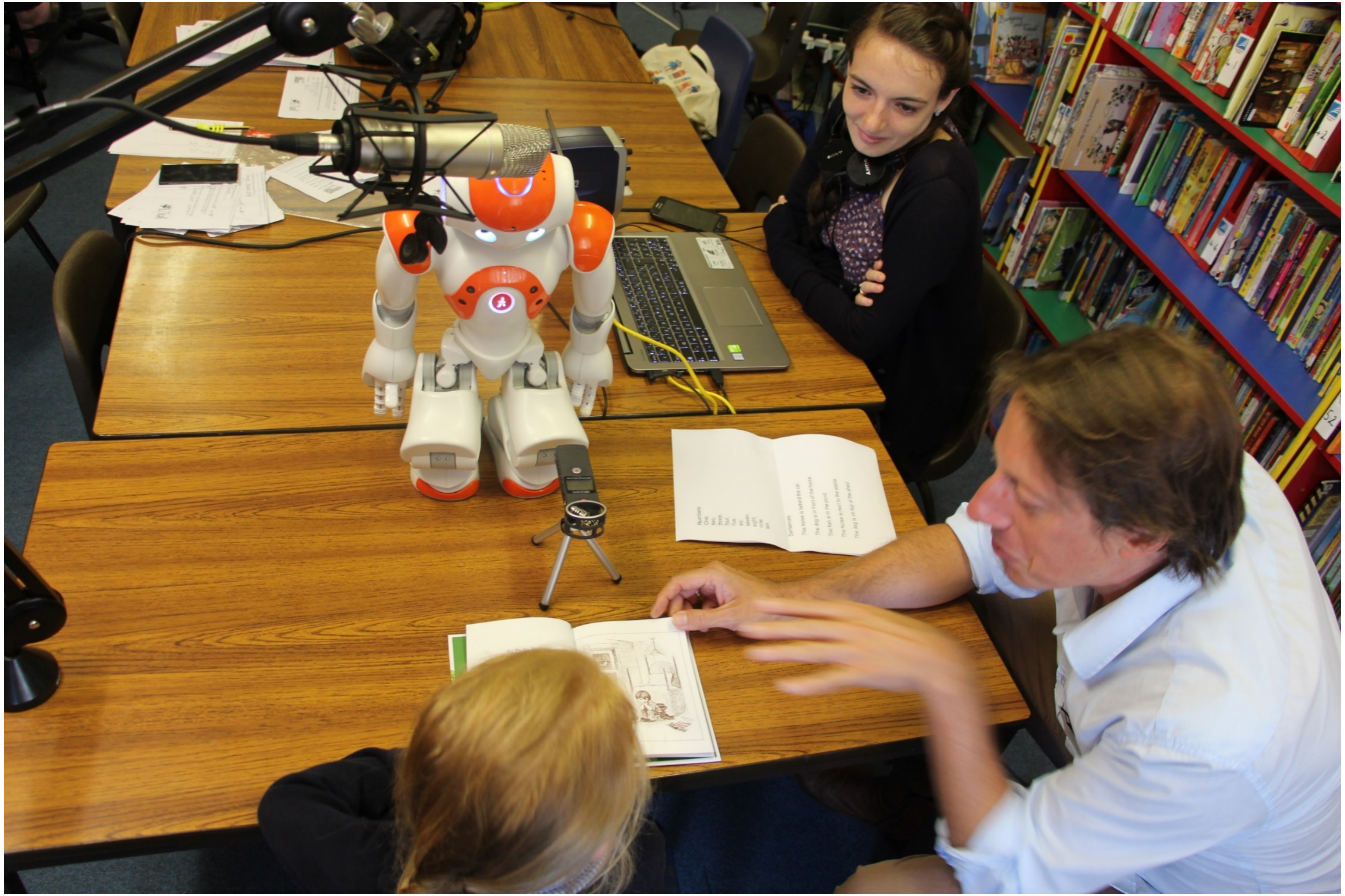
Companies that can create software with error rates falling in that ballpark are essentially matching the capabilities of humans, who miss roughly 5% of the words in a given conversation.

# Social signal processing

- The robot cannot provide an appropriate response when it cannot read its social environment.
- For example,  automated speech recognition (ASR) is still hugely problematic, especially for atypical populations

Youtube: Amazon Alexa Gone Wild!!!

GHENT UNIVERSITY · imec UNIVERSITY OF PLYMOUTH



GHENT UNIVERSITY · imec

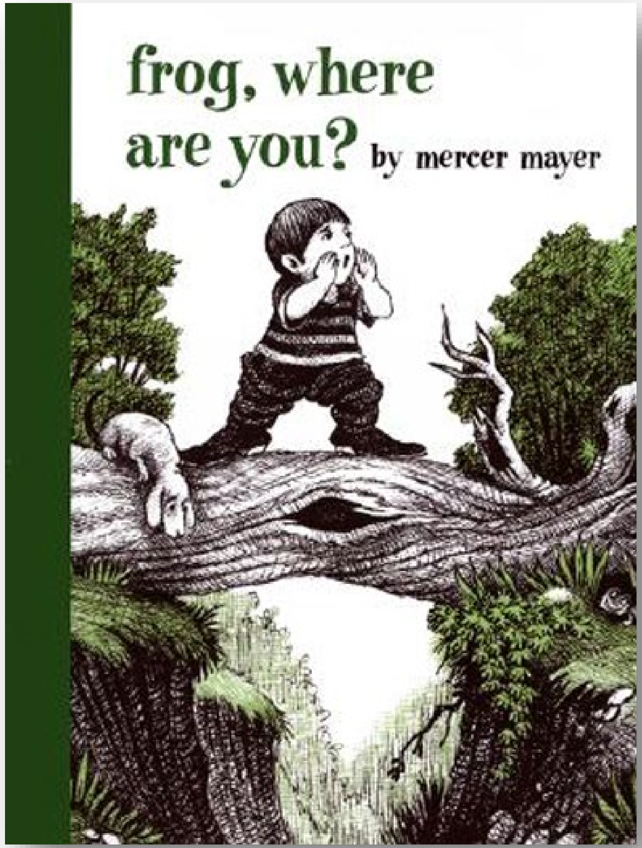
UNIVERSITY OF PLYMOUTH

# Methodology

Counting

“Open” speech

- Children’s speech in a school setting in England.
- 11 children, average age M=4.9, SD=0.3; 5F/6M
- Three kinds of utterances
  - Words (“one”, “two”, “three”, … )
  - Simple sentences (“The horse is in the stable”, … )
  - Spontaneous speech
- Three recording devices
  - NAO (V5.0, running NaoQi V2.1.4).
  - Studio grade microphone (Rode NT1-A)
  - Portable audio recorded (Zoom H1)



# Which is the best ASR?

| | Google | | Bing | | Sphinx | | Nuance | |
|---|---|---|---|---|---|---|---|---|
| | *M* LD [95%CI] | *% rec.* | *M* LD [95%CI] | *% rec.* | *M* LD [95%CI] | *% rec.* | *M* LD [95%CI] | *% rec.* |
| **fixed** (n=34) | 0.34 [0.24,0.44] | *11.8 [38]* | 0.64 [0.56,0.71] | *0 [0]* | 0.68 [0.64,0.73] | *0 [0]* | 0.76 [0.73,0.80] | *0 [0]* |
| **spontaneous** (n=222) | 0.39 [0.36,0.43] | *6.8 []* | 0.64 [0.61,0.67] | *0.5 []* | 0.80 [0.77,0.84] | *0 [0]* | 0.80 [0.78,0.82] | *0 [0]* |
| **spontaneous** clean only (n=83) | 0.40 [0.35,0.45] | *6.0 []* | 0.63 [0.58,0.68] | *1.2 []* | 0.78 [0.72,0.85] | *0 [0]* | 0.78 [0.75,0.81] | *0 [0]* |

6% to 38%

Range of recognition success of Google ASR engine with no grammatical constraints. **Google is the best performing engine (compared to Sphinx, Bing, and Nuance).**

GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

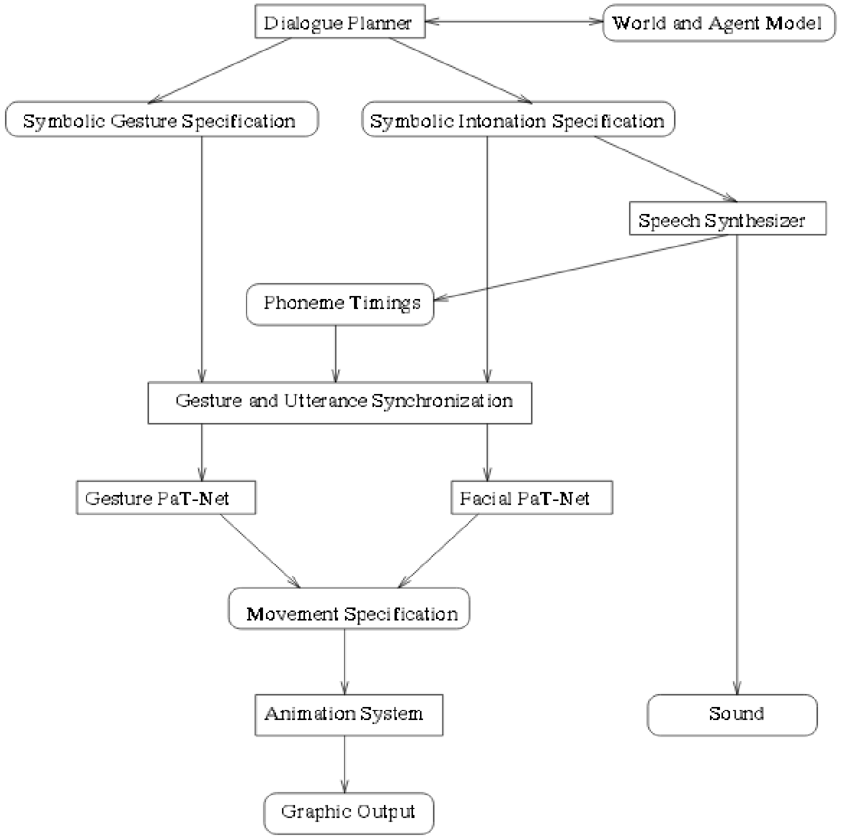
# Non-verbal communication

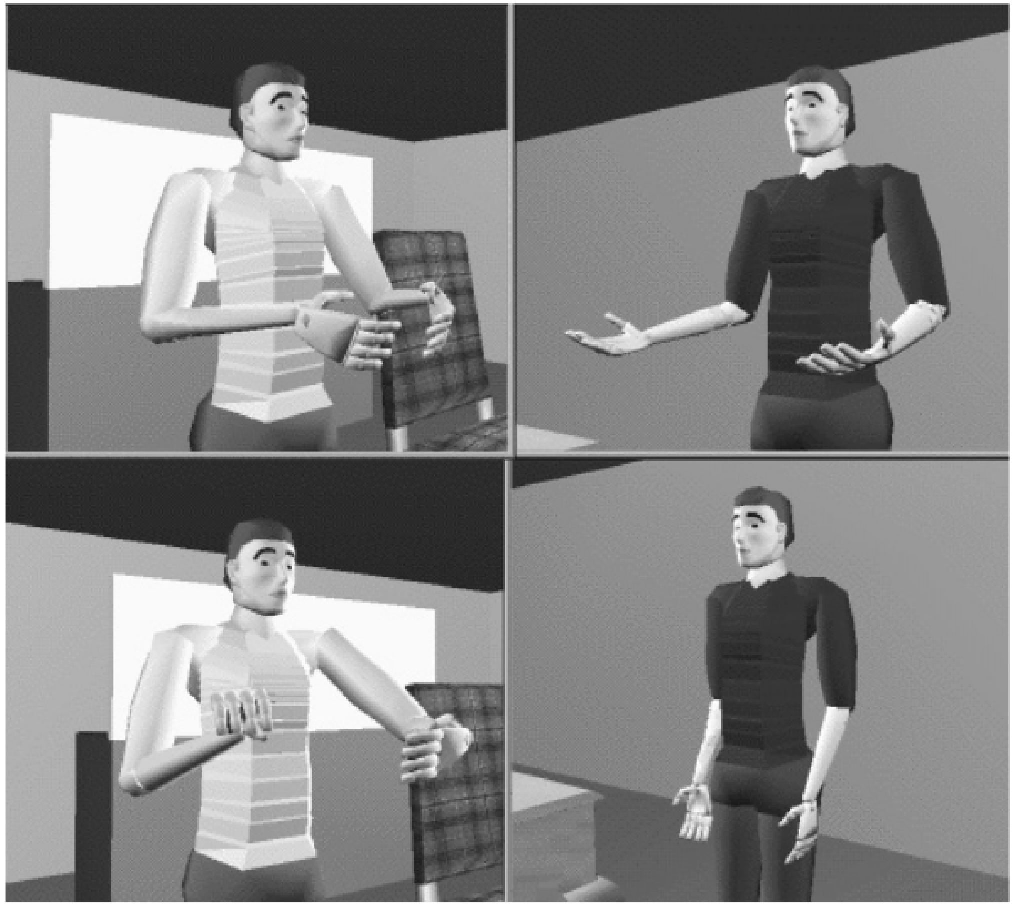
- Non-verbal aspect of interaction accounts for over 90% of semantic content.
- Co-speech gestures are of particular interest to HRI.
  - Iconic Gestures
  - Deictic Gestures
  - Metaphoric
  - Beat Gestures
- All have a role to play in interaction, e.g. beat gestures help preschoolers recall and comprehend discourse information




Llanes-Coromina, J., Vilà-Giménez, I., Kushch, O., Borràs-Comes, J., & Prieto, P. (2018). Beat gestures help preschoolers recall and comprehend discourse information. *Journal of Experimental Child Psychology*, 172.

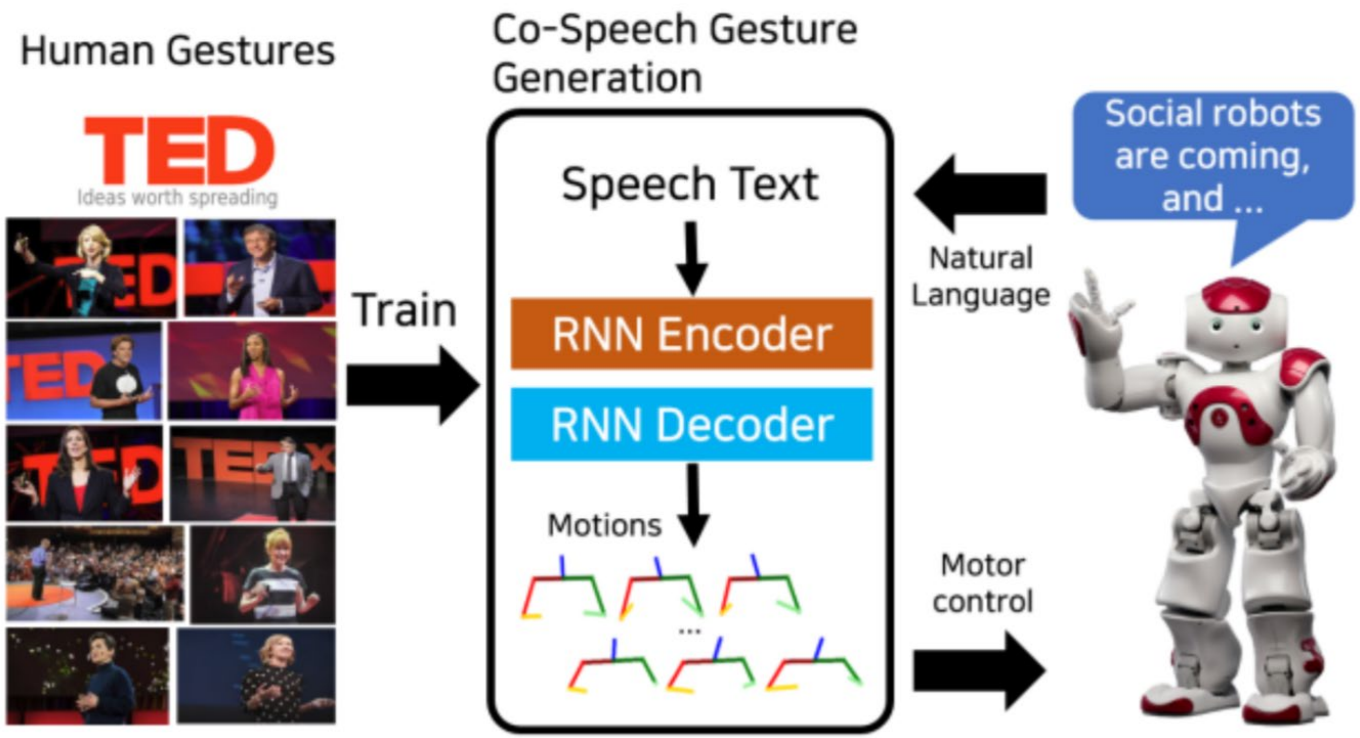
# 20+ years ago: rule-based co-speech generation



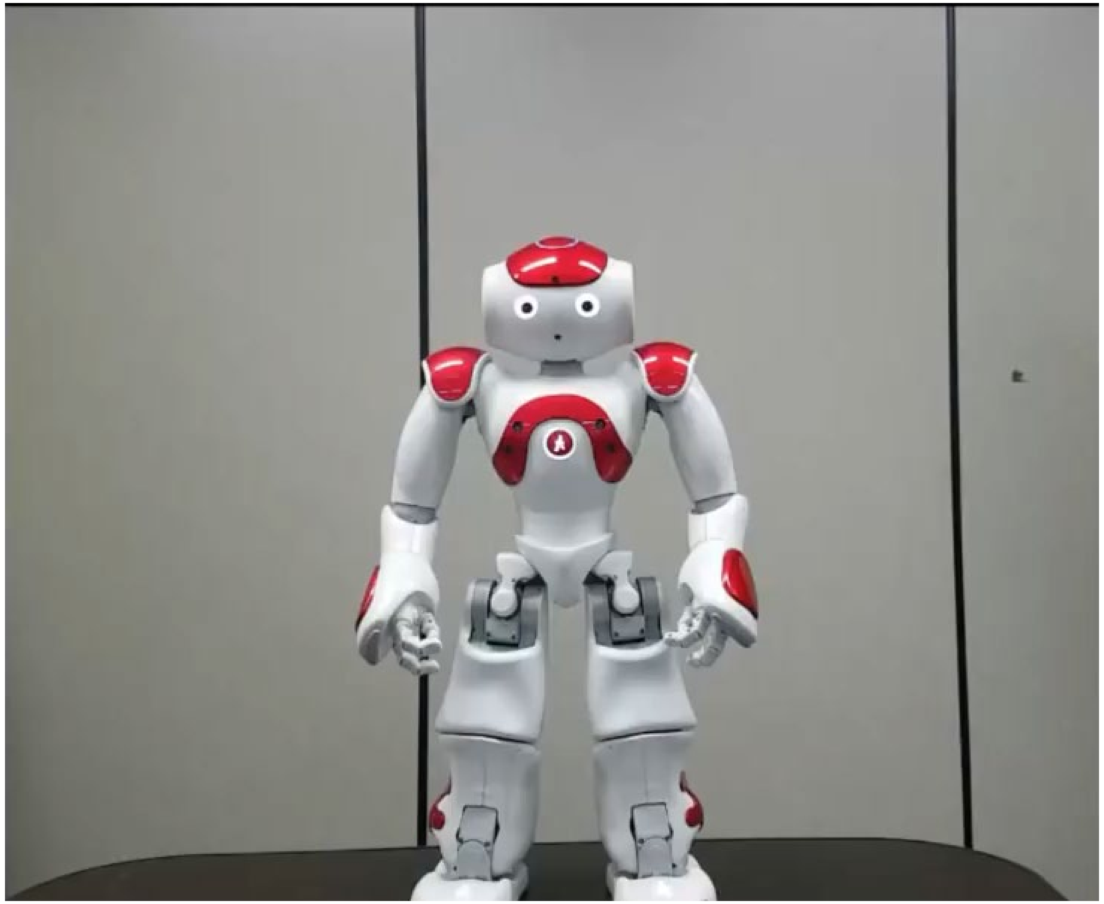
Cassell, J., Pelachaud, C., Badler, N., Steedman, M., Achorn, B., Becket, T., ... & Stone, M. (1994, July). Animated conversation: rule-based generation of facial expression, gesture & spoken intonation for multiple conversational agents. In *Proceedings of the 21st annual conference on Computer graphics and interactive techniques* (pp. 413-420).

# Data-driven co-speech gesture




Yoon, Youngwoo, Woo-Ri Ko, Minsu Jang, Jaeyeon Lee, Jaehong Kim, and Geehyuk Lee. "Robots learn social skills: End-to-end learning of co-speech gesture generation for humanoid robots." In ICRA. IEEE, 2019.

# Data-driven co-speech gesture



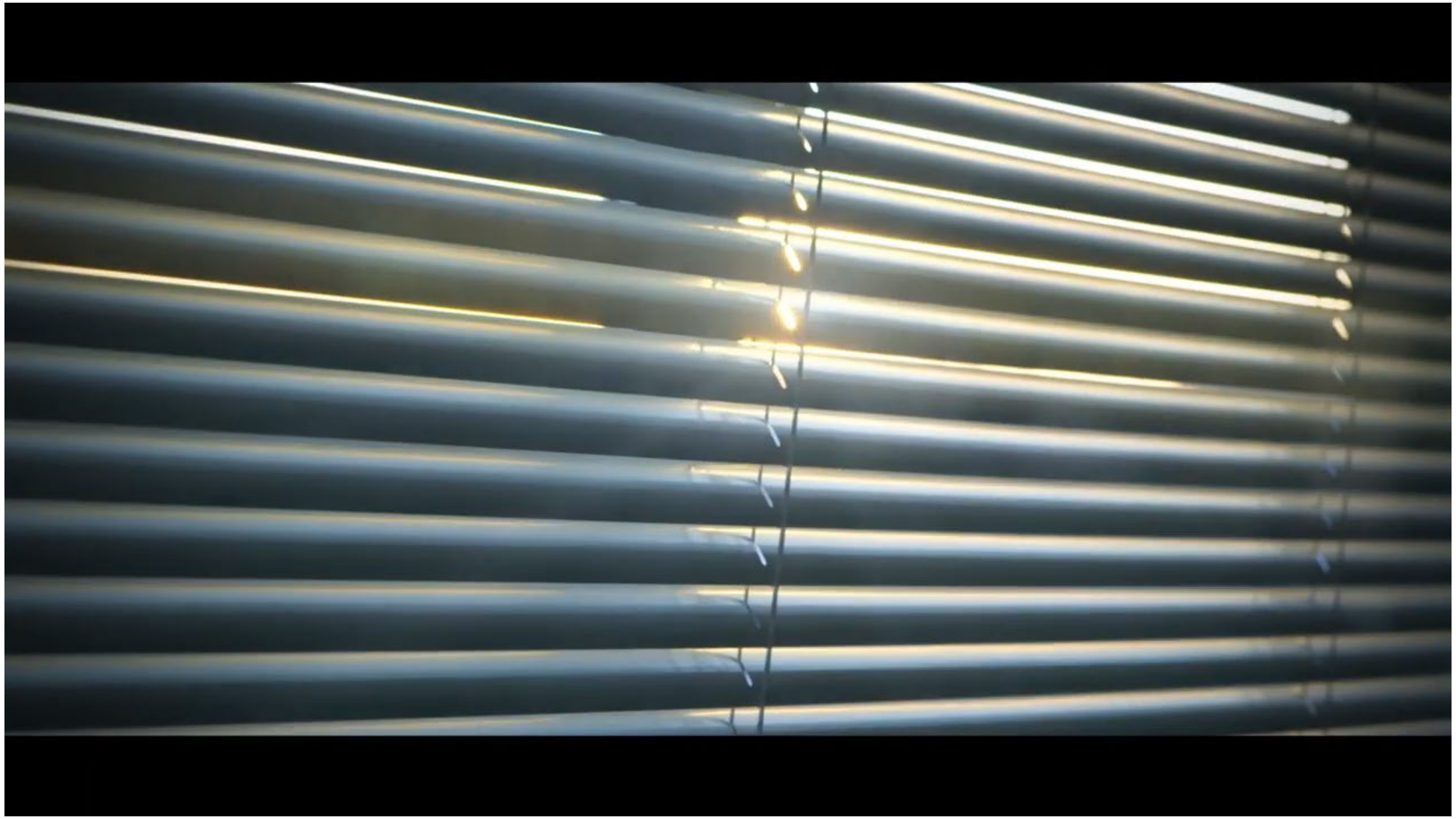
- Machine learning can achieve approx. 50% of the performance of people in co-speech gesture generation

- Match with the spoken message is still off, and naturalness is not optimal

GHENT UNIVERSITY · imec UNIVERSITY OF PLYMOUTH

Available at https://youtu.be/NLPEnIokuJw

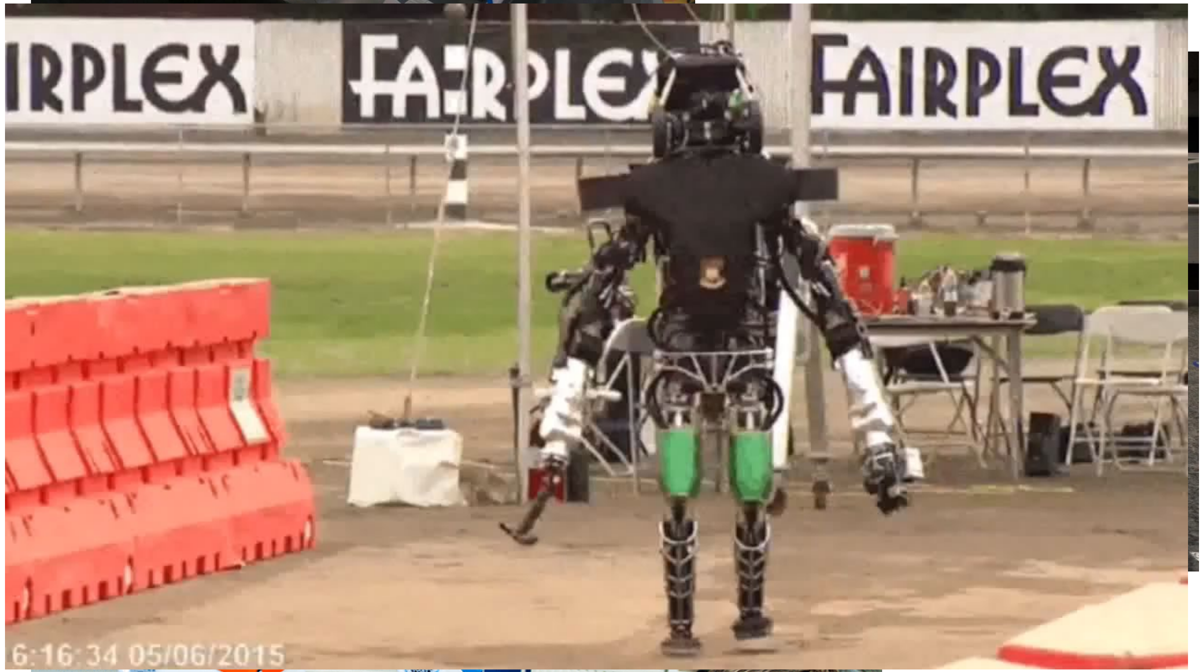
# Assisted living: Proof of concept



GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

# A call to arms for AI

- Interaction recruits all our cognitive faculties
  - Memory, perception, motor skills, language, …
- An effort by the entire AI department
- People and robots meet halfway
- Even simple systems can make a large impact




GHENT UNIVERSITY · imec · UNIVERSITY OF PLYMOUTH

# Thank you…

Pieter Wolfert, James Kennedy, Séverin Lemaignan, Charlotte Edmunds, Madeleine Bartlett, Serge Thill, Taras Kucherenko, …

The FP7 DREAM, FP7 ROBOT-ERA, H2020 L2TOR and CASTOR project teams.