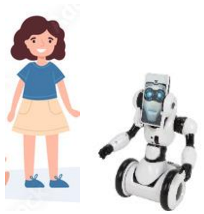
# Long-Term Social HRI

Lecture 9 – Socially Intelligent Robotics (SIR)

2023

# Scenario: Sarah and Mathbot

3 x 15 = 45



- Playful Interaction
- Fun
- Talk about hobbies

12 / 4 = 3

“When the school is closed I like to watch movies on the big digiboard”

- Conversational Interaction
- Companion
- Talk about dreams

“Did you go pony riding this weekend like you hoped?”

- Emotional Interaction
- Ingroup
- Talk about fears

# What is long-term HRI?

Sustained engagement and interaction between humans and robots over an extended period of time

- Recurring sessions
- Length of each session
- Frequency / time-span

Technology is/was not there or robust enough.

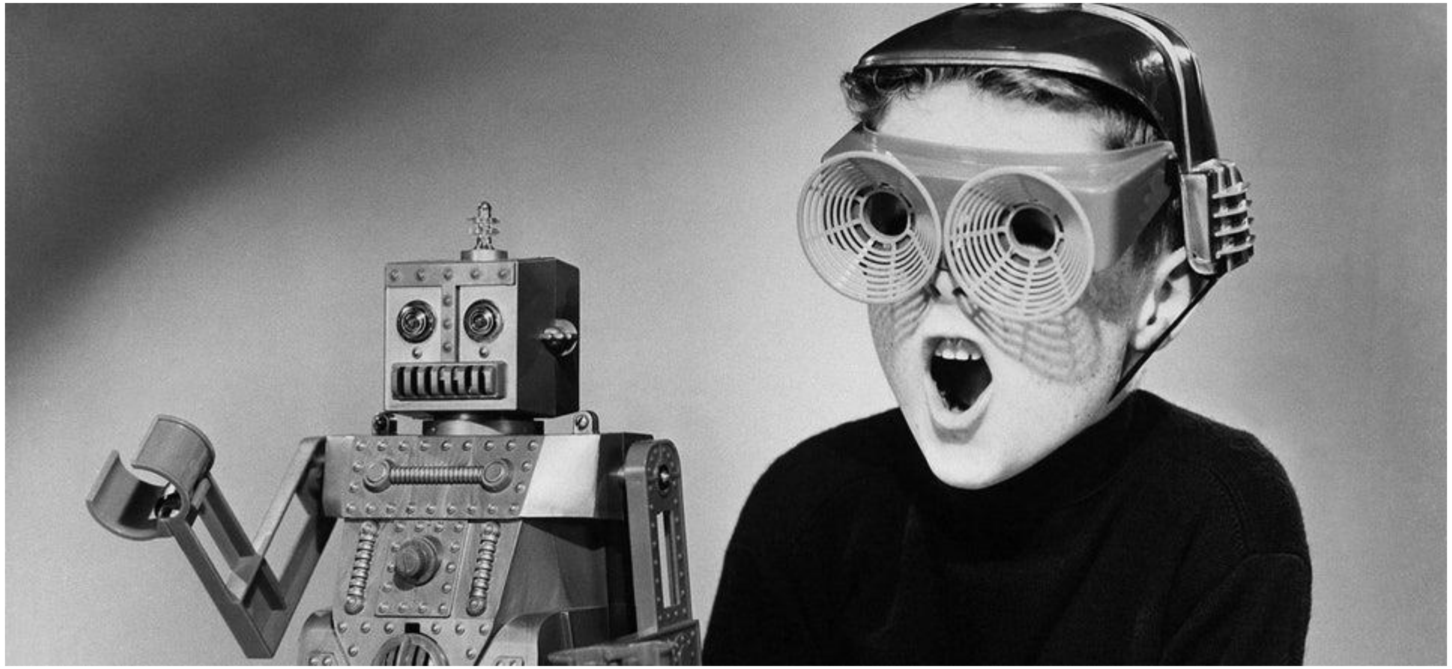
Time consuming, especially in situ

Lacking theoretical foundation

Hesitant adoption. Only a recent shift in need due to (expected) labour shortages.

Why is it so understudied?

# Why is it important to study?



- Ecological validity
- Moving past the novelty effect

Join at menti.com | use code 4981 8753

# What capabilities do we need for long-term HRI?

Waiting for responses

# Long-Term Memory and Continuity

**WHY**

Safeguard coherence, consistency, and continuity of interaction

**WHAT**

1. Episodic memory: store and recall specific episodes / events.
    - Identify and collect relevant information
    - Representation of information
    - Relevant retrieval of information
2. Temporal handling
3. Semantic handling
4. Hierarchical handling
5. Emotional / affective handling
6. Integration with other data sources

# Long-Term Memory and Continuity

**QUESTIONS**

- What information do we need to store?
- Security and privacy safeguards are crucial.
- Do we need human-like feature like consolidation and selective forgetting?

# Long-Term Adaptation and Personalization

**WHY**

1. The more attuned the person and the robot are the more effective the interaction will be.
2. Personalization is essential for relationship building.

**WHAT**

- Long-term = more data = more opportunity for adaption and personalization
- *Performance*: more levelled feedback and tailored training
- *Preferences*: from preset to preference learning
- *Interpersonal characteristics:* relatively stable, but subject to change due to life events.
- *Inclusivity*: more time to adapt to (cultural) norms even though system designers were oblivious.

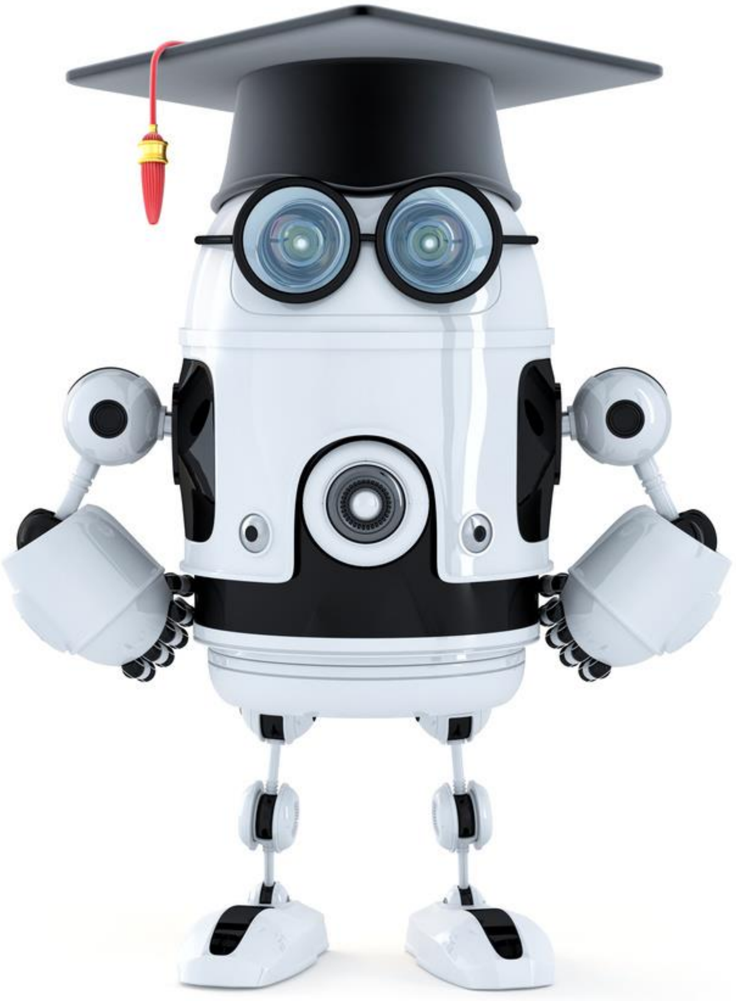
# New Skills and Dynamic Learning / Teaching

**WHY**

- Remain relevant
    - People’s needs change over time
    - Enjoy new functionalities
- General rule: specific robots are more effective than general robots.

**WHAT**

- “App store” versus dynamic learning / teaching
- Traditionally dynamic learning / teaching is used for physical tasks.
- Giving people more control over interaction supports willingness to continue.
- Enable the robot to learn and people to teach the robot new social features could be a win-win.



# Development in Interaction Content

**WHY**

- Adding a narrative development to the interaction content provides them with opportunities to be invested in the interaction

**WHAT**

- Storylines
- Character development
- Transmedia (auxiliary) content

# **Vision** – Interaction as a serial TV-show

- Conversation is the core
- Each session is a new episode
- Child and robot are main actors
- Supportive role for parents, medical professionals, and researchers
- Overarching narrative between episodes
- Co-created with professional writers

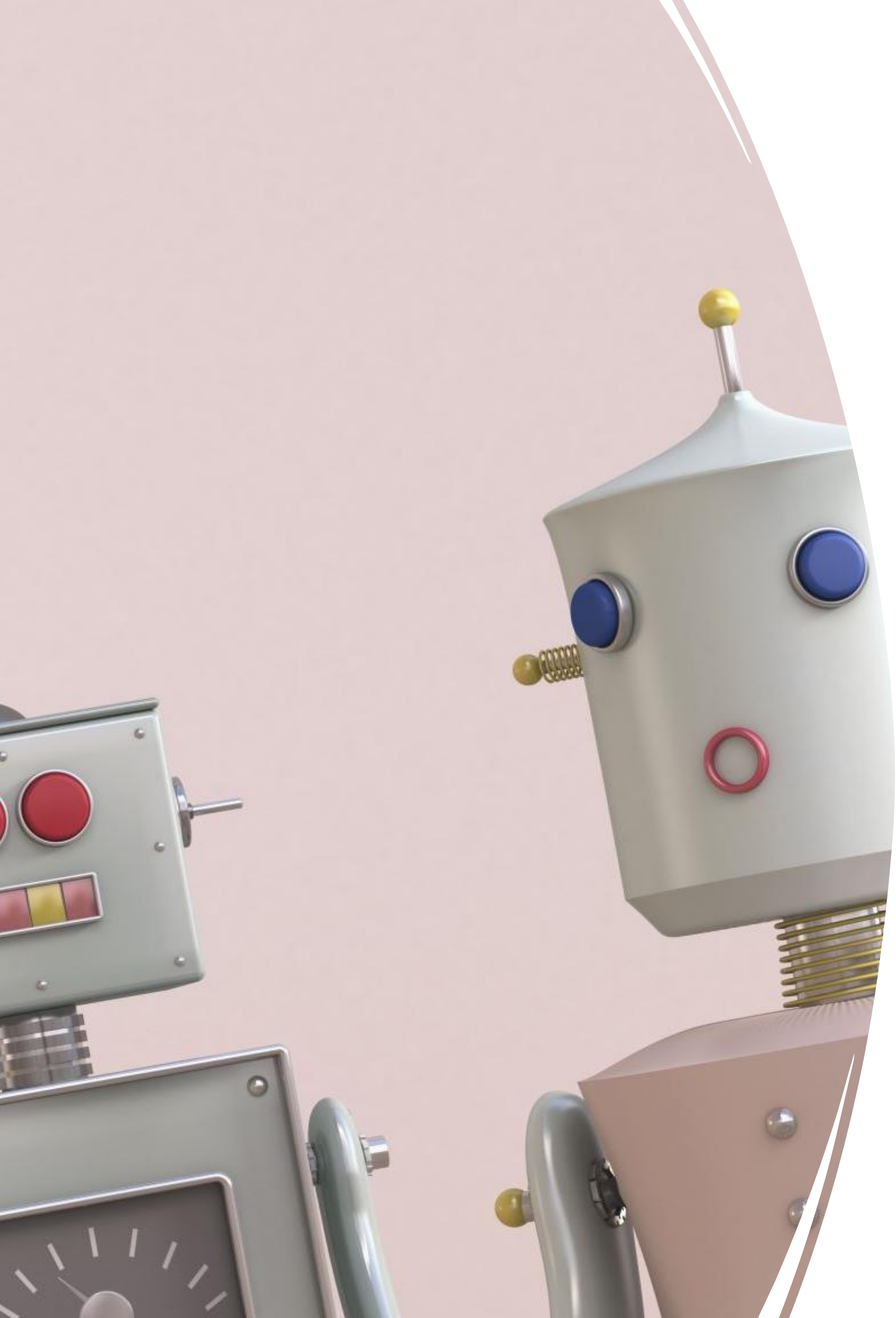
  

# Content Creation in Collaboration with Writers, Theater Makers and other Artists

# Predictive Modeling for Future Interactions

Anticipate future user needs and proactively addressing.

# Aging and Long-Term User Changes



# Relationship Building and Maintenance

People have a natural tendency to relate themselves or even bond with interactive devices.

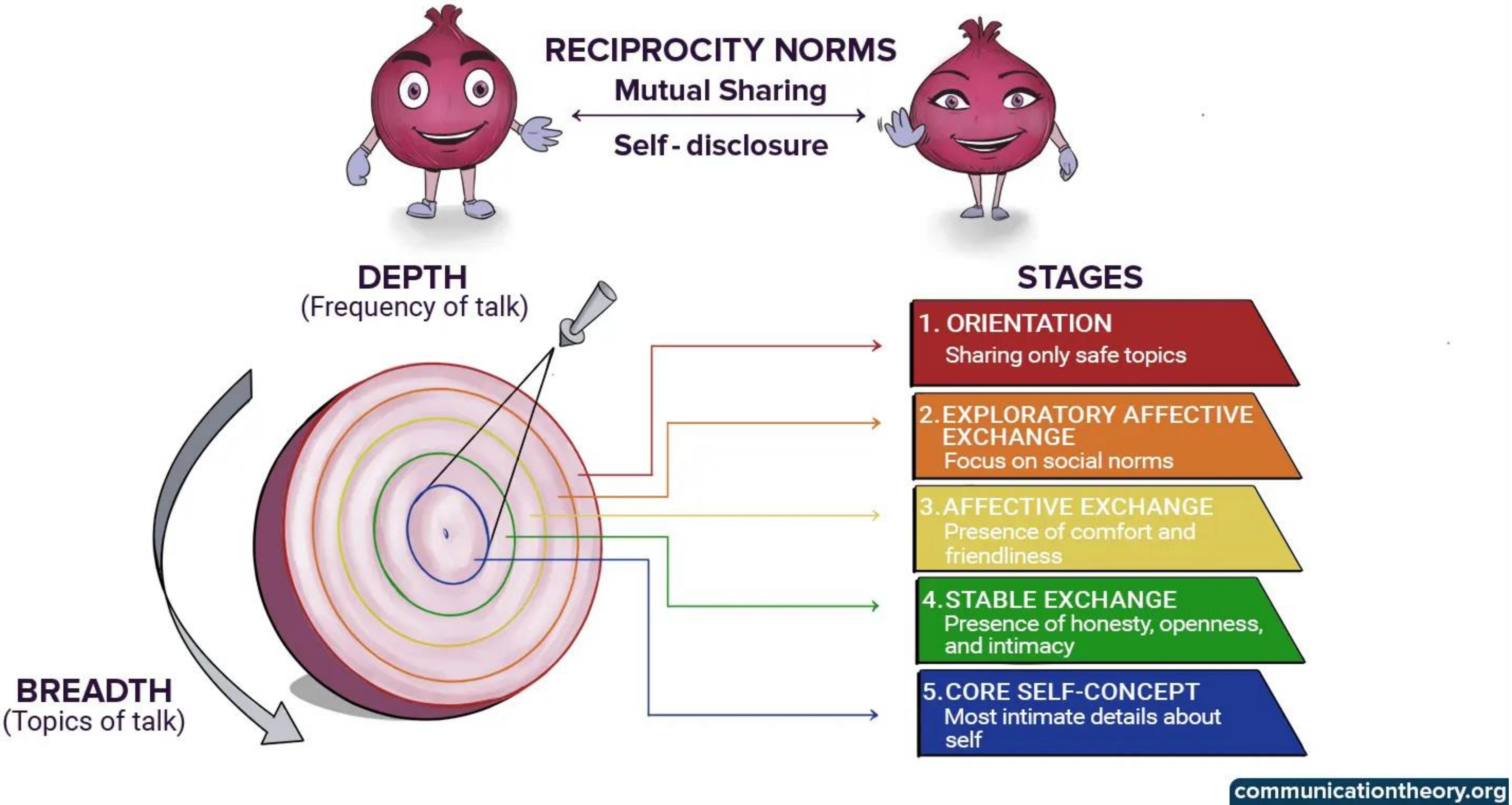
This tendency is only stronger when the robot’s appearance resembles familiar entities (humanoid, zoomorphic, cartoons).

This tendency is even stronger when the robot exhibits social behaviors.

It needs to be addressed!

**Experiencing a relationship is a more sustainable motivation for interaction than the novelty effect.**

# SOCIAL PENETRATION THEORY



# Interactional Needs | Social Psychology

- **Social Responsiveness**
  - Children want to be seen and heard by the robot.
  - Increases predictably and lowers stress to interact.

- Response to every attempt of communication:
  - Acknowledge its existence
  - Address the content
  - Inline with expected response
  - Timely

**Reciprocation** (to self-disclosure)

- Children want to get something meaningful back from the robot.

- Uncertainty reduction
- Balancing risk

- Key factor for child-child and child-robot relationship formation

# Relationships over time| Developmental Psychology

- A child's first relationship is with their parents.
- Social-cognitive developments paired with going to school brings many relational changes from the age of 6.

**6.**

Learning to individuate from parents

Discovering their place in the world

Open to friendships with others.

# Relationships over time| Developmental Psychology

**7.**

- Relationships with other adults (teachers)
- Developing empathy and emotion regulation
- Can follow ‘rules’ of conversation

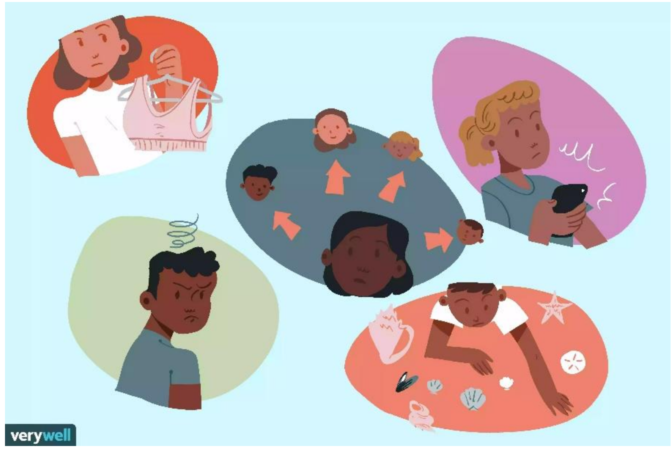
**8.**

- Close friendships with peers of same sex
- Interests, friends, relationship with family help establish a self-identify

# Relationships over time| Developmental Psychology

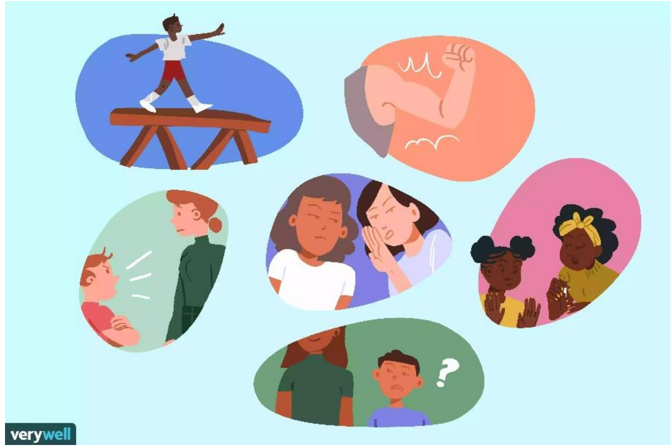
**9.**

- Desire to belong to a group
- Play more with opposite sex
- Recognize other people have different perspectives
- Develop a sense of justice



**10.**

- Deepening friendships but also more volatile relationships
- In- and outgroup more important
- Experience peer pressure



# Assignment 1: Operationalize Theories

1. Pick an age and developmental milestone
2. Choose either social responsiveness or reciprocation
3. Produce a concrete requirement for the robot that addresses this pair.

For example:

**10** Ingroup + Social responsiveness:

When responding to the child the robot should acknowledge they both belong to the same ingroup.

## 6.

- Learning to individuate from parents
- Discovering their place in the world
- Open to friendships with others.

## 7.

- Relationships with other adults (teachers)
- Developing empathy and emotion regulation
- Can follow ‘rules’ of conversation

## 8.

- Close friendships with peers of same sex
- Interests, friends, relationship with family help establish a self-identify

## 9.

- Desire to belong to a group
- Play more with opposite sex
- Recognize other people have different perspectives
- Develop a sense of justice

## 10.

- Deepening friendships but also more volatile relationships
- In- and outgroup more important
- Experience peer pressure

### Social Responsiveness

- Children want to be seen and heard by the robot.

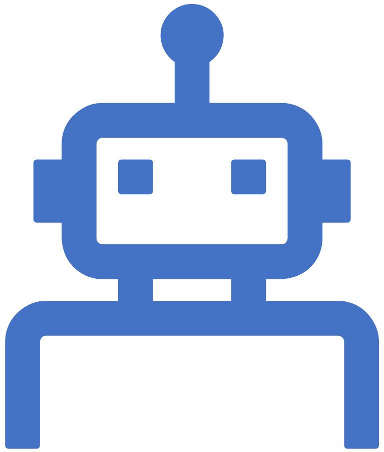
### **Reciprocation** (to self-disclosure)

- Children want to get something meaningful back from the robot.

### Assignment

Produce a concrete requirement for the robot.

# Assignment 2: How can the robot help?



1. Exchange the requirement with a neighbor.
2. Produce a robot behavior that addresses the requirement.

For example:

To acknowledge ingroup membership the robot includes a common ingroup catch phrase in its response.

# Research Motivation

Hero

**Supportive Long-Term Child-Robot Interaction**

- Extended stay in hospital OR recurring visits
- Regular (weekly) sessions
- Short (5-30 min) interventions

# Design Foundation

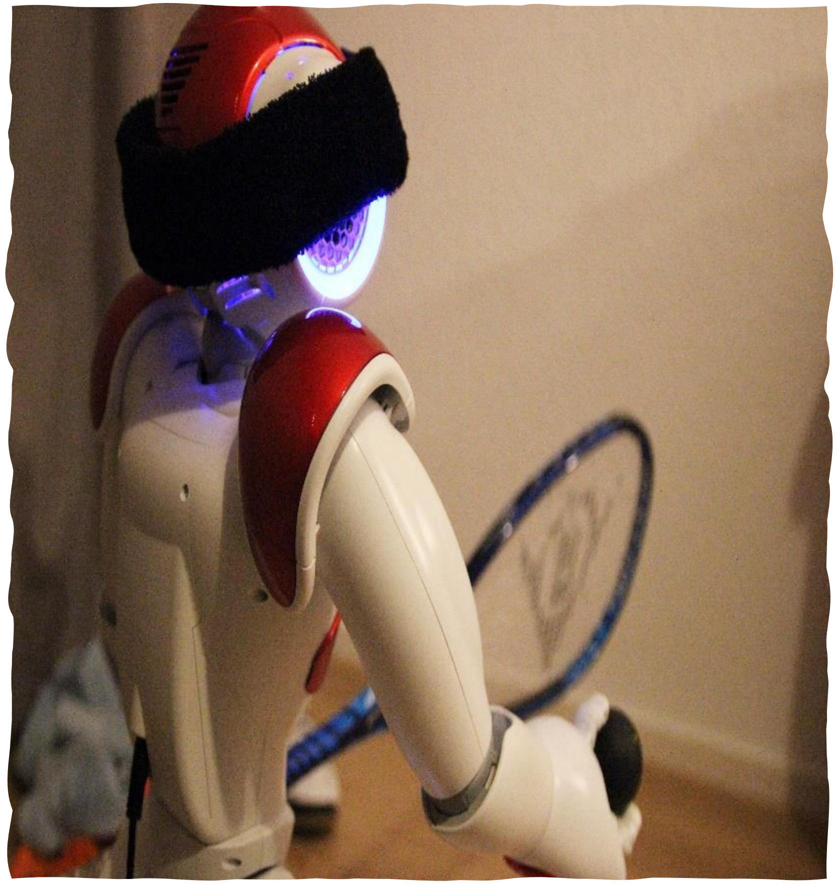
- How to **foster** the child-robot relationship?

  - Reciprocity by providing Novel Content and Narrative Development
    - Introducing novel content over time is crucial (Leite et al., 2013)
    - Adding a narrative development makes it more gripping (Lwin, 2010)

  - Continuity of interaction
    - Recall things about past conversation and child to make it a more personal conversation. (Leite et al., 2013)

  - Similarity
    - Sharing interests facilitates relationship formation (Parks & Floyd, 1996).
    - Drawing from shared experiences, creating a common ground, strengthens the relationship. (McKinley et al., 2017)

# Design Specification – Mini-dialogs



- **Narrative Mini-dialogs**
  - Sequential dialogs with a storyline
  - Multiple narratives interwoven in conversation
  - *Examples: Robot Olympics and Dreaming*

- **Chitchat Mini-dialogs**
  - Topic based dialogs
  - Topic-opener, follow-up, stand-alone
  - *Example: Favorite food*

- **Functional Mini-dialogs**
  - *Example: Greeting or goodbye*

# Design Specification – Mini-dialogs

- Ordered list of sentences / utterances
- Templated dialog
- *"My favorite animal is a [fav_animal] as well!"*
- Optionally dependent on other mini-dialogs
- Sentences can be conditional
- *e.g. If fav_animal == cat*
- Designer creates a session template providing a rough outline of the conversation for each session.

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child's name
  - Personal
  - Conversational
- **Content Selection**
  - Narrative Choices
  - Topic Selection
- **Content Augmentation**
  - Greeting
  - Content Motivation
  - Foreshadowing

Personalization

*Versus*

Control

# Design Specification – Memory-based Personalization

- **Memory References**
  - **Child's name**
  - Personal
  - Conversational
- **Content Selection**
  - Narrative Choices
  - Topic Selection
- **Content Augmentation**
  - Greeting
  - Content Motivation
  - Foreshadowing

Hi [name], nice to see you

*Versus*

Hi, nice to see you

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child's name
  - **Personal**
  - Conversational
- **Content Selection**
  - Narrative Choices
  - Topic Selection
- **Content Augmentation**
  - Greeting
  - Content Motivation
  - Foreshadowing

You like [sheep] right?

*Versus*

I learned about dogs

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child's name
  - Personal
  - **Conversational**

- **Content Selection**
  - Narrative Choices
  - Topic Selection

- **Content Augmentation**
  - Greeting
  - Content Motivation
  - Foreshadowing

Last time you mentioned [ice cream]

*Versus*

I saw someone eat pizza

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child's name
  - Personal
  - Conversational

- **Content Selection**
  - **Narrative Choices**
  - Topic Selection

- **Content Augmentation**
  - Greeting
  - Content Motivation
  - Foreshadowing

Persistant across sessions

*Versus*

Only immediate

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child’s name
  - Personal
  - Conversational
- **Content Selection**
  - Narrative Choices
  - **Topic Selection**
- **Content Augmentation**
  - Greeting
  - Content Motivation
  - Foreshadowing

Child’s interest

*Versus*

Fixed

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child’s name
  - Personal
  - Conversational
- **Content Selection**
  - Narrative Choices
  - Topic Selection
- **Content Augmentation**
  - **Greeting**
  - Content Motivation
  - Foreshadowing

Personal secret handshake

*Versus*

Default wave

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child’s name
  - Personal
  - Conversational
- **Content Selection**
  - Narrative Choices
  - Topic Selection
- **Content Augmentation**
  - Greeting
  - **Content Motivation**
  - Foreshadowing

Let’s talk about you favorire sport, [taekwondo]

*Versus*

Let’s talk about a cool sport, football

# Design Specification – Memory-based Personalization

- **Memory References**
  - Child's name
  - Personal
  - Conversational
- **Content Selection**
  - Narrative Choices
  - Topic Selection
- **Content Augmentation**
  - Greeting
  - Content Motivation
  - **Foreshadowing**

Let's talk about [risotto] next time

*Versus*

I hope to make pizza someday

# *Implementation*
# Artificial Cognitive Agent (GOAL)

- Folk psychology interpretation of cognitive notions such as **goals**, **actions**, **beliefs**, and **perception** to structure its operational processing.

- Agent programming language GOAL (Prolog)

- GOAL agent uses
    - session template
    - memory (user model + conversation history)
    - meta-data of mini-dialogs (e.g. thread/topic membership and dependencies)
- to select best fitting next mini-dialog.

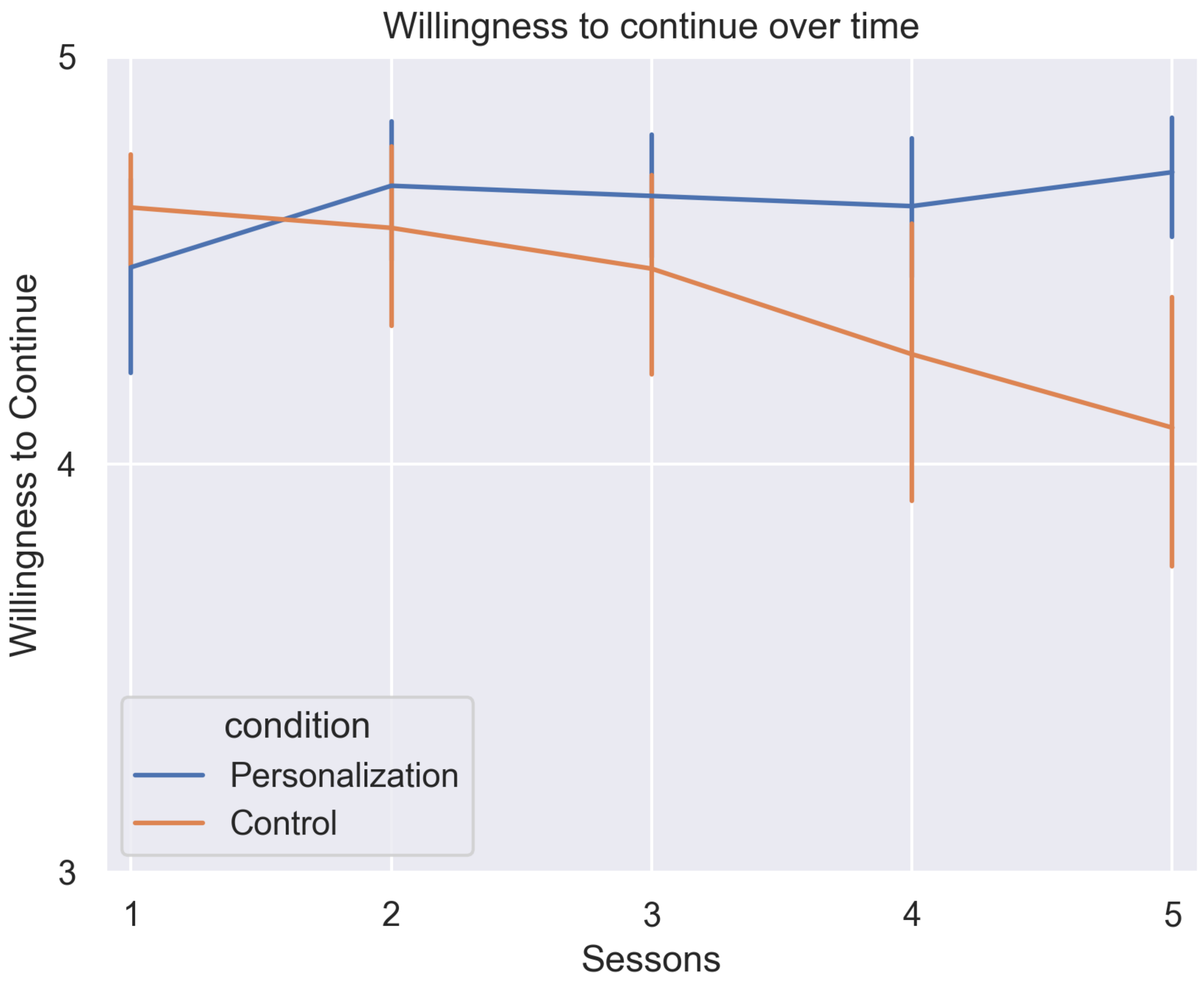
- GOAL agent dynamically
    - populates templated dialog
    - resolves conditionals

# Longitudinal User Study

- **Interaction:** 46 children (8-10 y.o.) - 5x 15-minute conversations in 2-months
- **Hypothesis 1:** children will a) feel closer, b) self-disclose more, and c) show more positive social cues to a robot that uses memory-based personalization.
- **Hypothesis 2**: children are more willing to continue interacting with a robot that uses memory-based personalization.

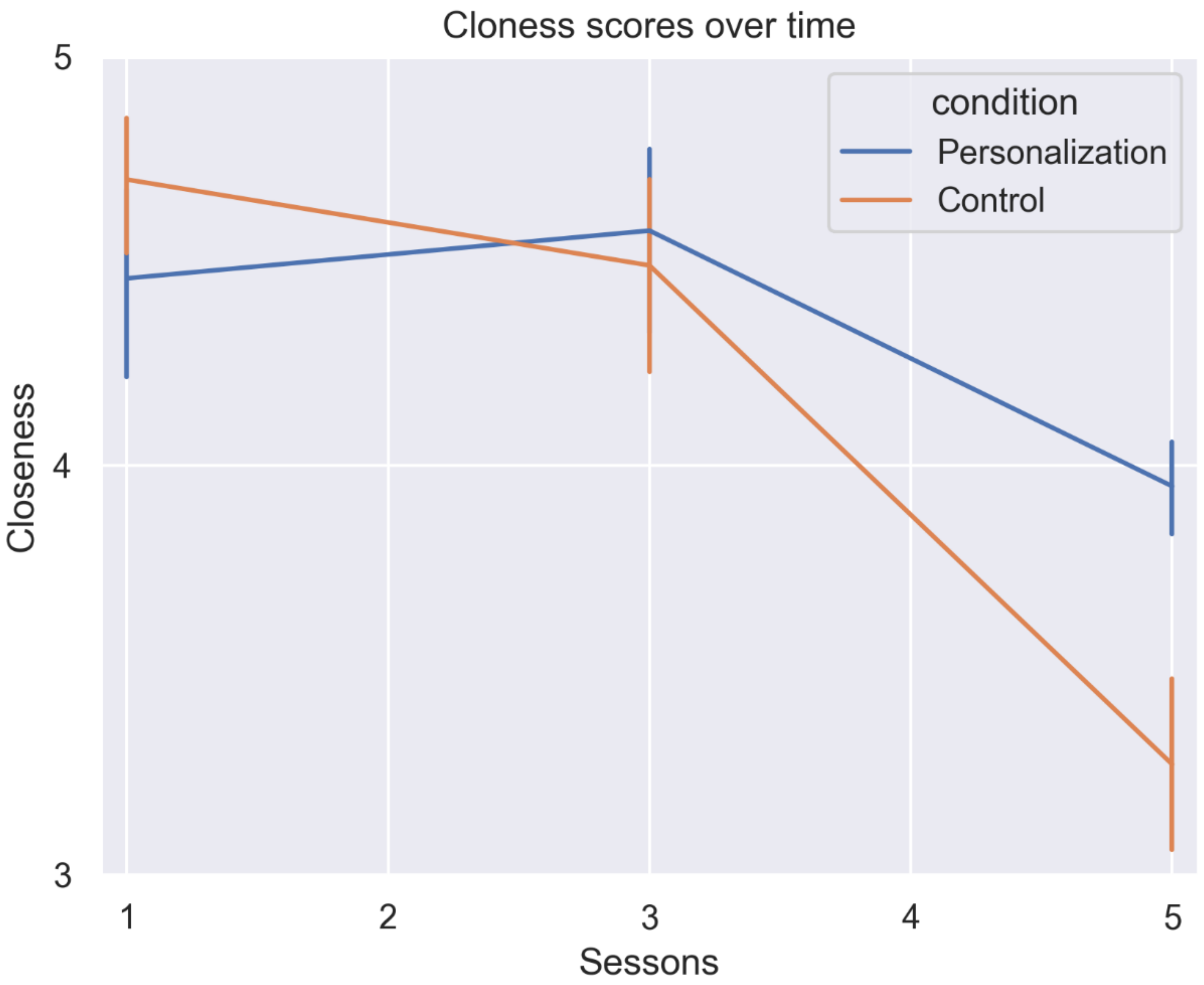
- **Measures**
  - Closeness
  - Self-disclosure
  - Valence of social cues
  - Willingness to continue

# Results



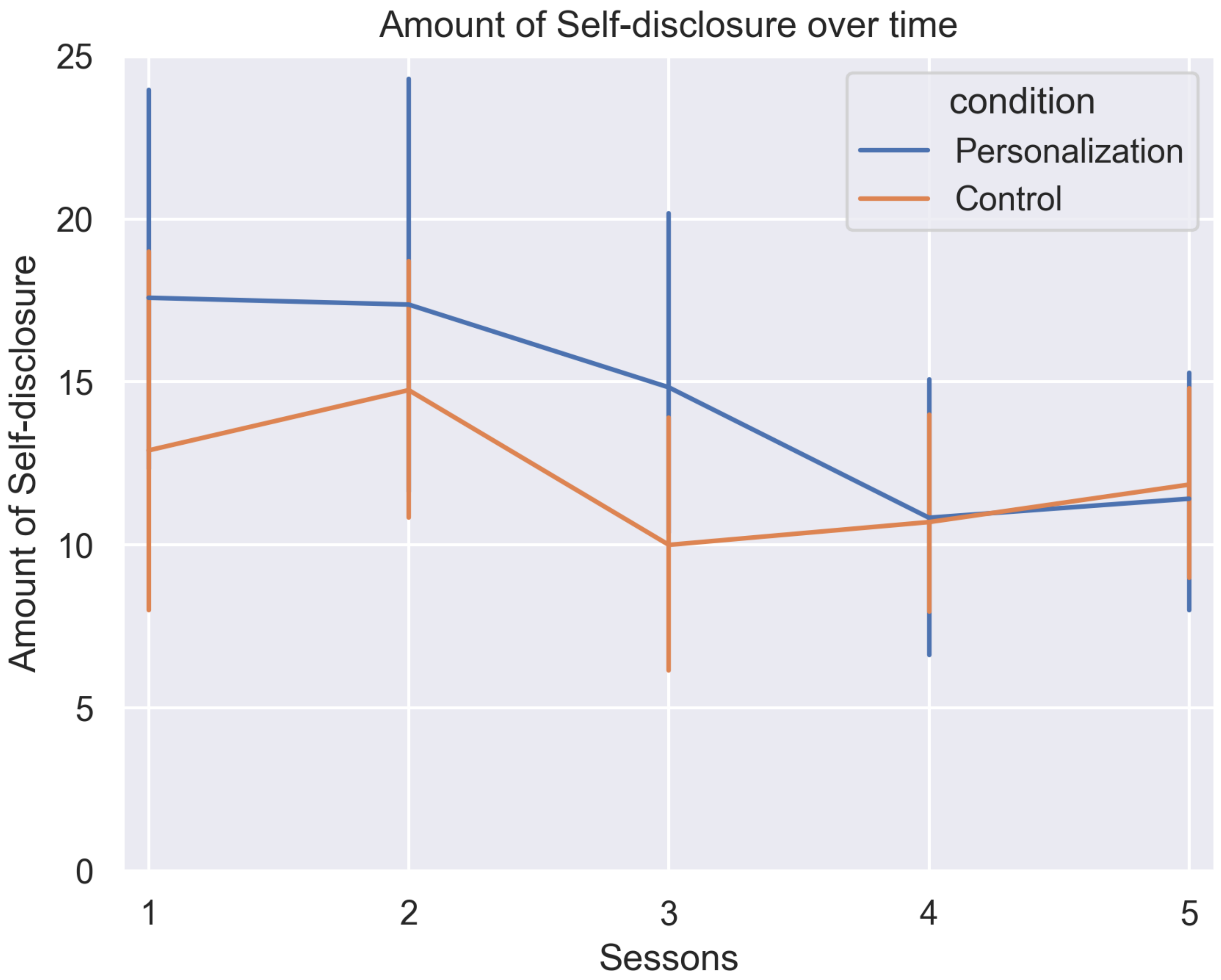
Willingness to continue over time
5
4
3
Willingness to Continue
1
2
3
4
5
Sessons
condition
Personalization
Control

# Results



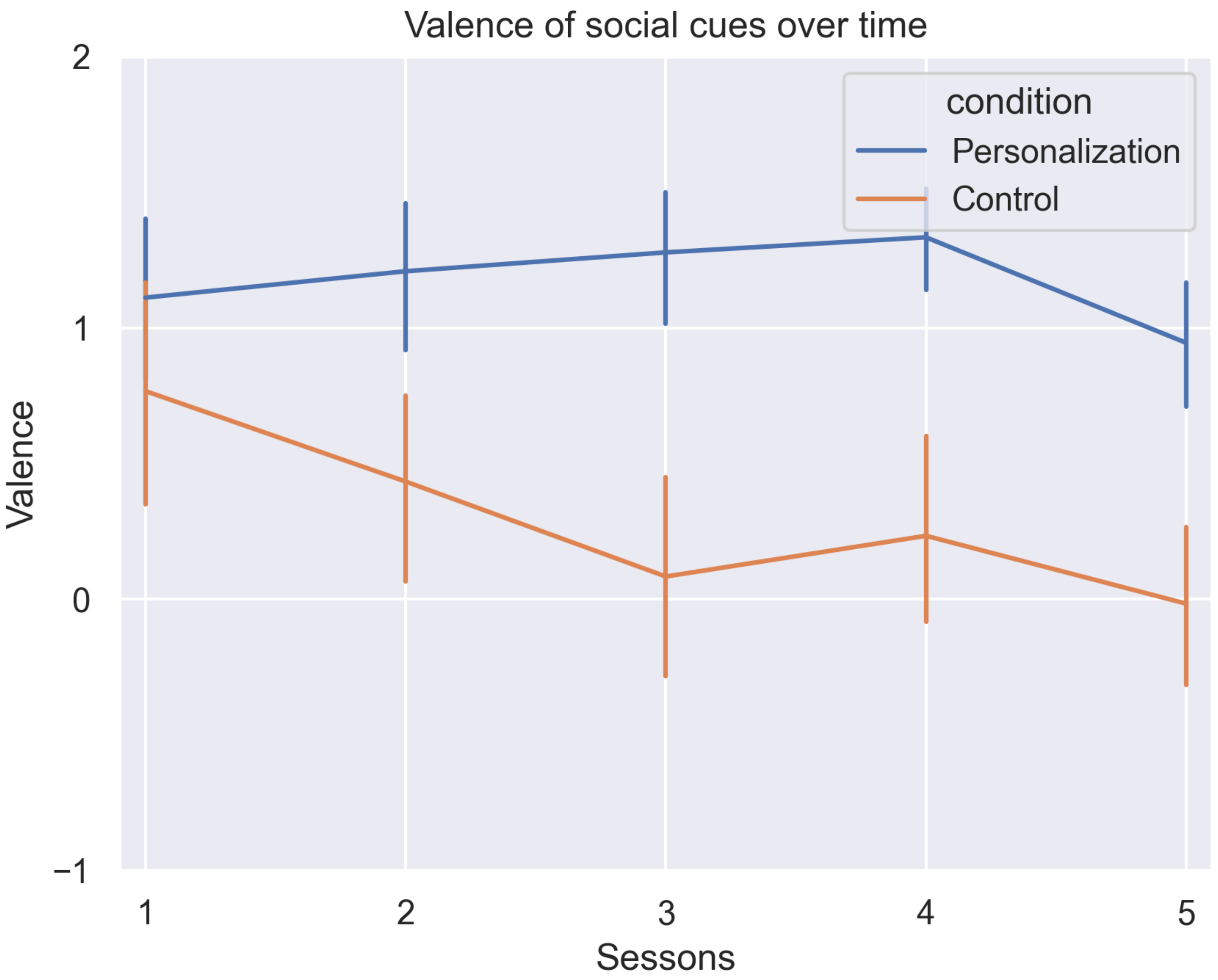
Cloness scores over time
condition
Personalization
Control
Closeness
Sessons
5
4
3
1
2
3
4
5

# Results



Amount of Self-disclosure over time
Amount of Self-disclosure
Sessons
condition
Personalization
Control
0
5
10
15
20
25
1
2
3
4
5

# Results


Valence of social cues over time
condition
Personalization
Control
Valence
2
1
0
−1
1
2
3
4
5
Sessons

Application Context

# SOROCOVA

www.sorocova.nl

The New York Times

## *The Pandemic Erased Two Decades of Progress in Math and Reading*

The results of a national test showed just how devastating the last two years have been for 9-year-old schoolchildren, especially the most vulnerable.

Give this article 1.5K

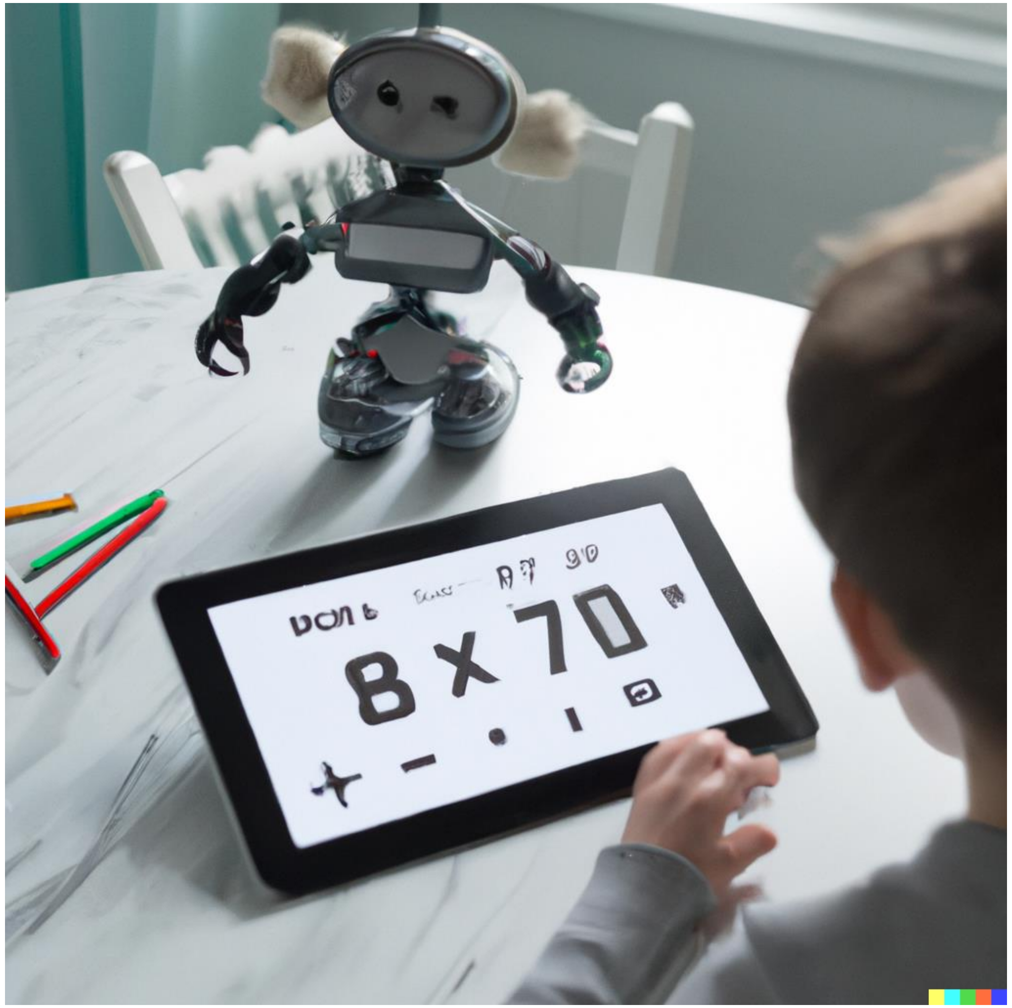
unicef | for every child

## COVID:19 Scale of education loss 'nearly insurmountable', warns UNICEF

*Media factsheet*

24 January 2022

# Social Robots in Math Education




- The potential for social robots in education is well established.
- Math education is under represented.
- Child-tablet interaction with robot providing feedback.
- Social behaviors can distract from educational task.

How to better *intertwine* the social behaviors and the math task?

Design Rationale I

# Social Constructivism

**Social Constructivist Perspective I** (Lynch, 2016)

- Learning is a shared, social, process.
- Knowledge development happens through social interaction and language use.

**Social Constructivist Perspective II**

- Social relevancy: familiarity of and connection with (robot) teacher is key for successful learning

Design Rationale II

# Realistic Math Education (RME)

Key characteristics (Van den Heuvel-Panhuizen and Drijvers, 2014)

- Active
- Realistic
- Schematic
- Holistic
- Interactive
- Scaffolding

Success experience (Jansen et al. 2013)

# Design Requirements

The child-robot math interaction needs to:

1. Intertwine social behavior with the math task;
2. contribute to Relationship formation;
3. provide a grounded Reality for the math problems;
4. Scaffold the learning process by providing guidance at the right time;
5. provide children with an experience of Success

Design Specifications

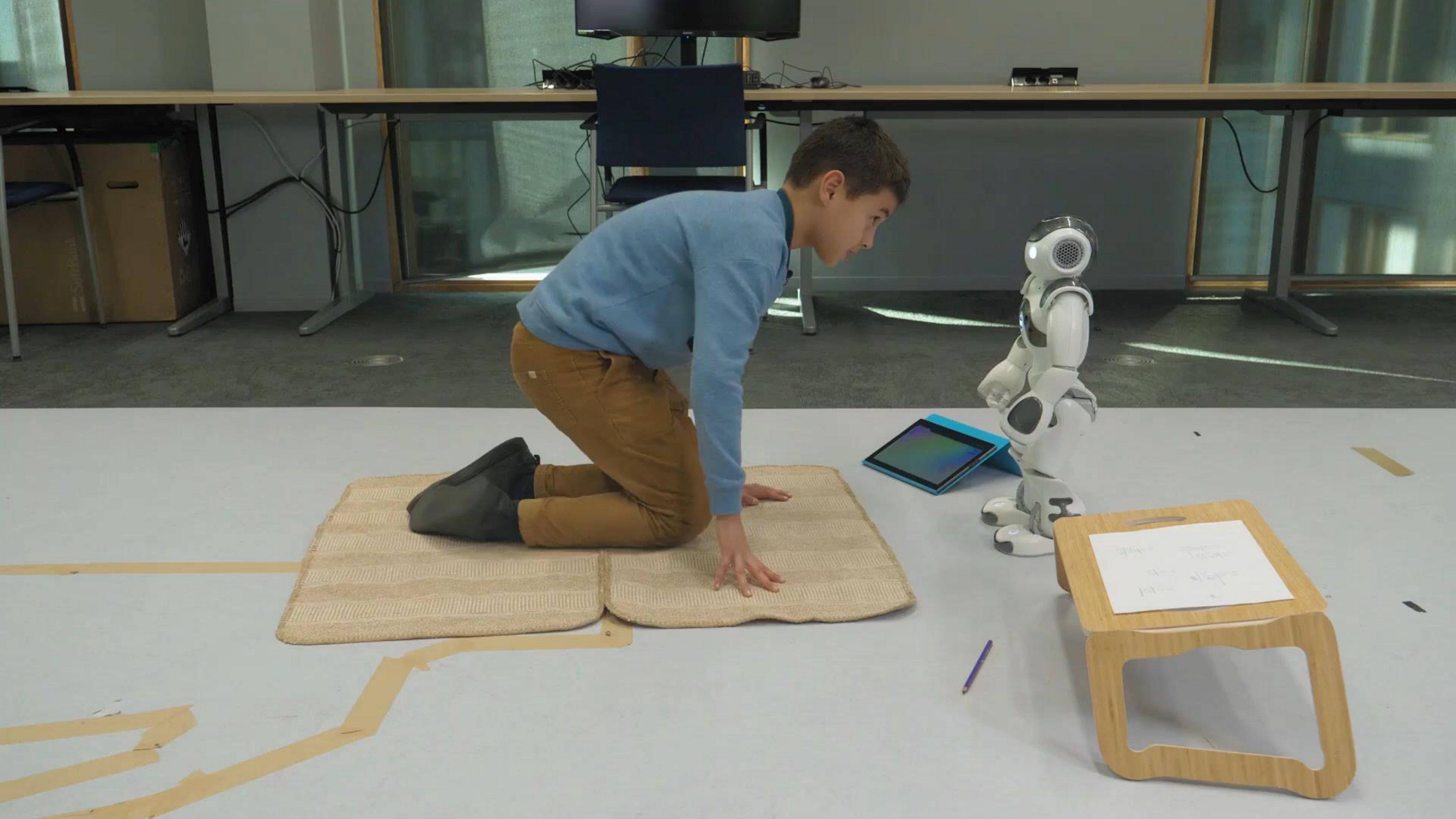
# Math Conversation

- Child and robot chat about
  - Child’s interests, hobbies, and preferences.
  - Robot’s past jobs and robot friends.
- Multiplication problems part of each robot anecdote.
- Robot asks child for help to solve it.
- Robot checks the math.
- No judgement after an incorrect answer.
- Praise for the effort (not the answer).

Intertwine

Reality

Success

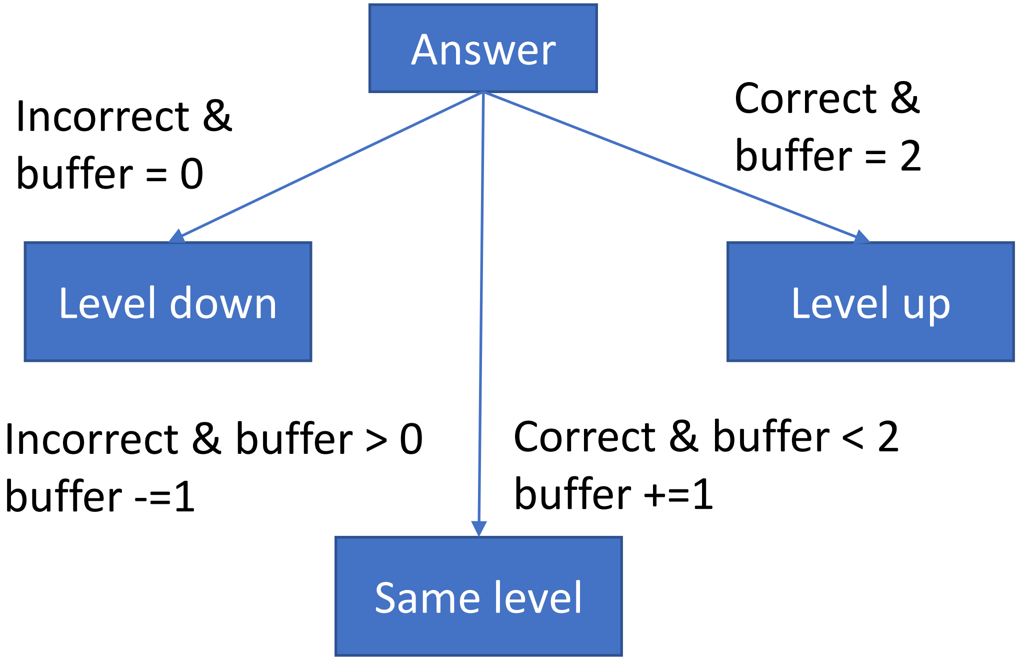


Design Specifications

# Math Level Adaption

Success

- Doing math with the right level of complexity is key for optimal learning (Zone of Proximal Development)
- 12 difficulty levels
- Starting level: 2




| Level | Pattern | Example |
|---|---|---|
| 0 | {3, 5, 10} x [2, 10] | 5 x 8 |
| … | | |
| 4 | [2, 10) * 10 x [2, 10) * 10 | 30 x 40 |
| … | | |
| 11 | [11, 100) x [11, 100) | 34 x 65 |

Design Specifications

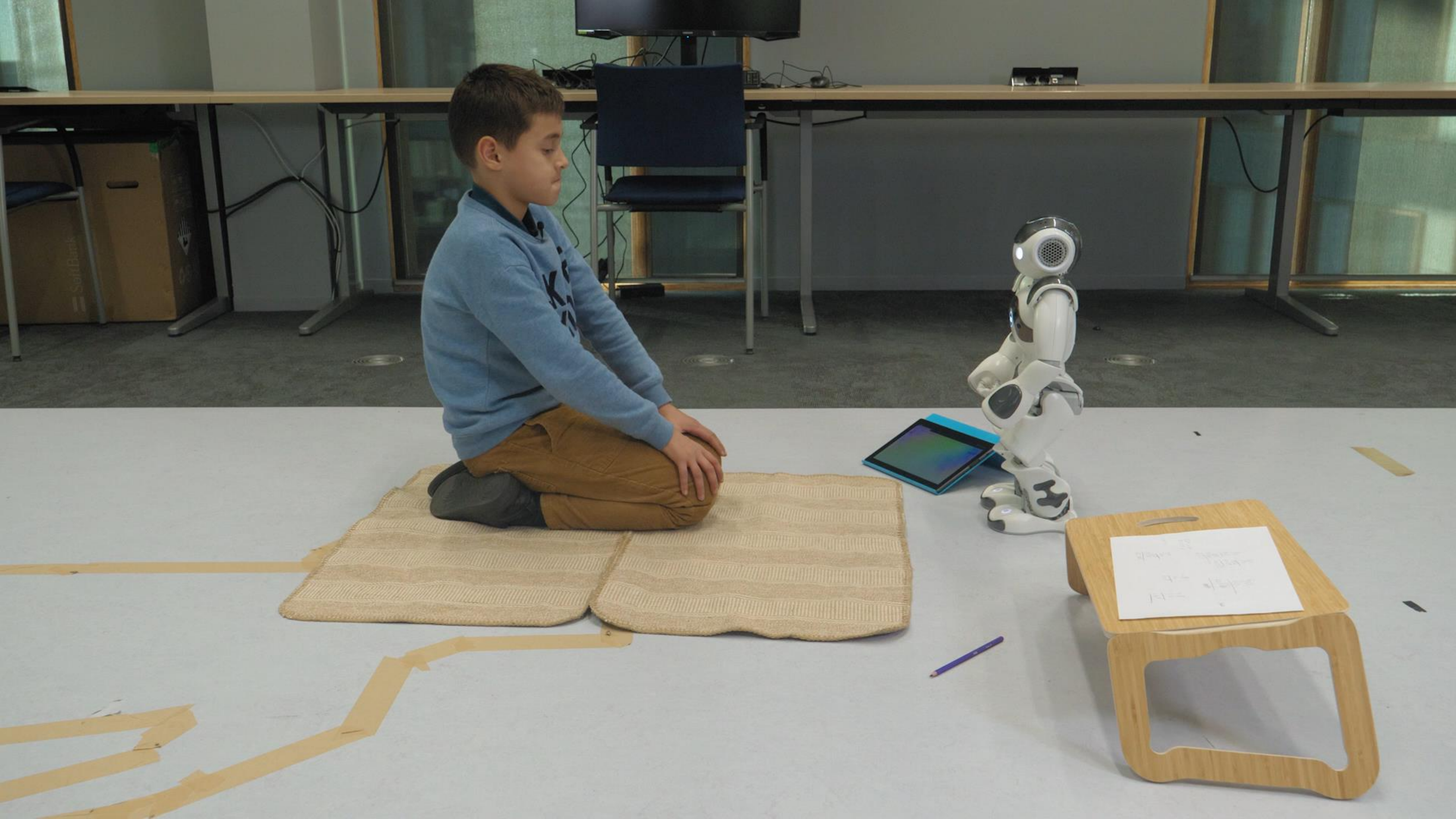
# Personalization

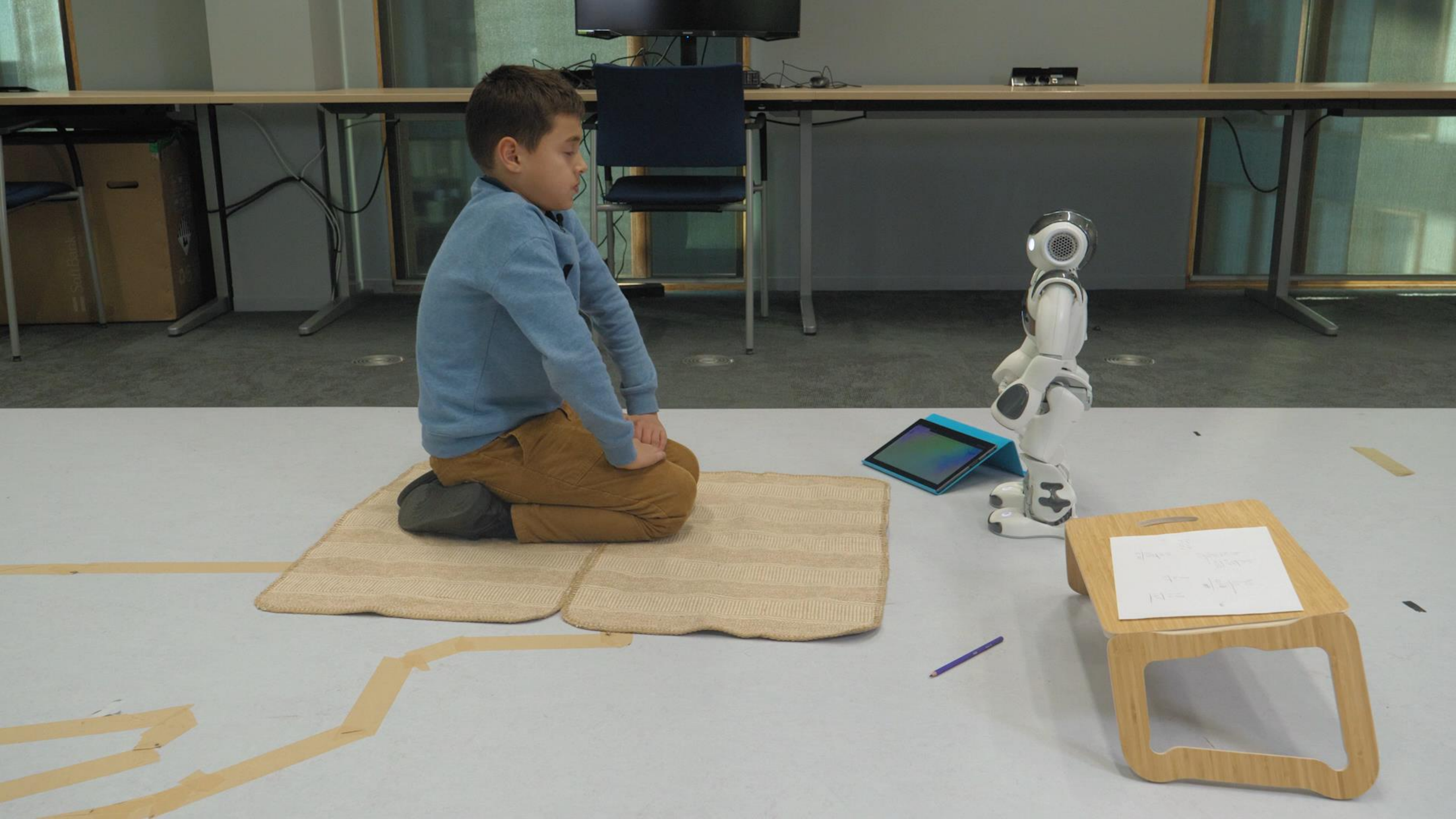
- Memory-based personalization to make the conversation more personal
  - Robot remembers child's name
  - Robot refers to children's hobbies and interests.
  - Robot continues past conversations.
  - Children co-create a "secret" handshake with the robot that is used as a personalized greeting and goodbye

Relationship

Intertwine

- Personalized math conversation
  - The topics of the math dialogs are match children's interests and hobbies.



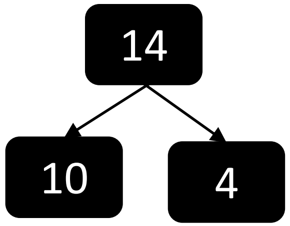


Design Specifications

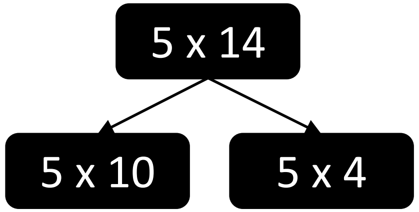
# Scaffolding

**Progressive Schematization** (RME method)

Scaffold




- Support development models for mathematical concepts
- and informal solution strategies.
- Guide patterns and rule discovery.




**After a mistake or upon request**

- Based on informal solution strategy
- The robot breaks down the problem into intermediate steps.
- Verbally and visually on tablet.

# Hypotheses

## Child’s Math Performance

- We hypothesized personalization and scaffolding will increase children’s math performance.

## Robot’s Sociability

- We hypothesized that personalization will increase
  - Social presence
  - Feelings of friendship
- We hypothesised that scaffolding will increase
  - Social presence

# Methods

- 130 children (9-10 y.o.) from 6 different primary schools
- 3 session within a week
- 17 min of interaction per session
- 2x2 between-subjects design
  - With vs without personalization
  - With vs without scaffolding (guidance)
- Math performance
  - Answer correct (ratio)
  - Time to solve (average seconds)
- Robot’s sociability
  - Social presence
  - Feelings of friendship

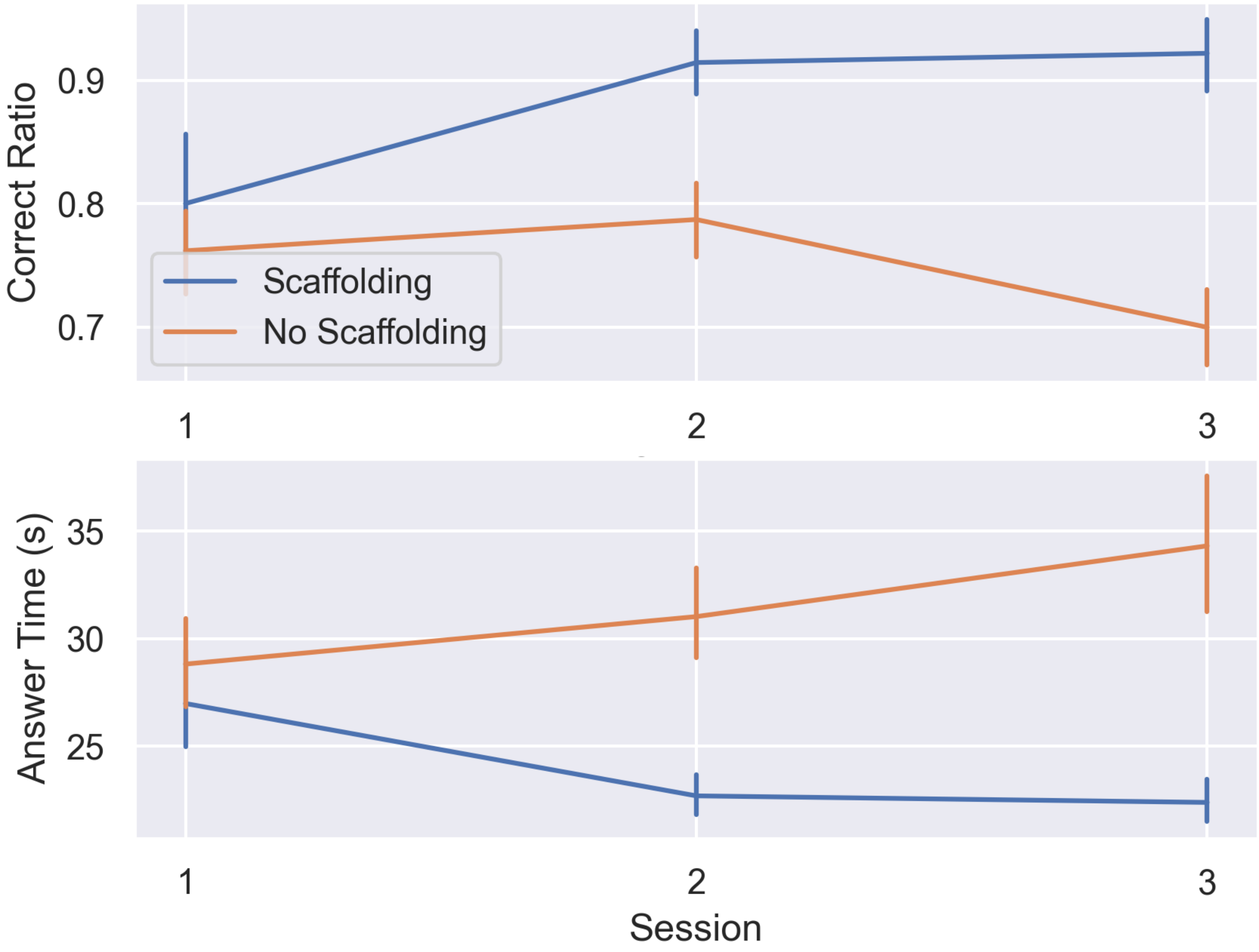
# Math Performance

- Difference between personalization conditions not statistically significant.

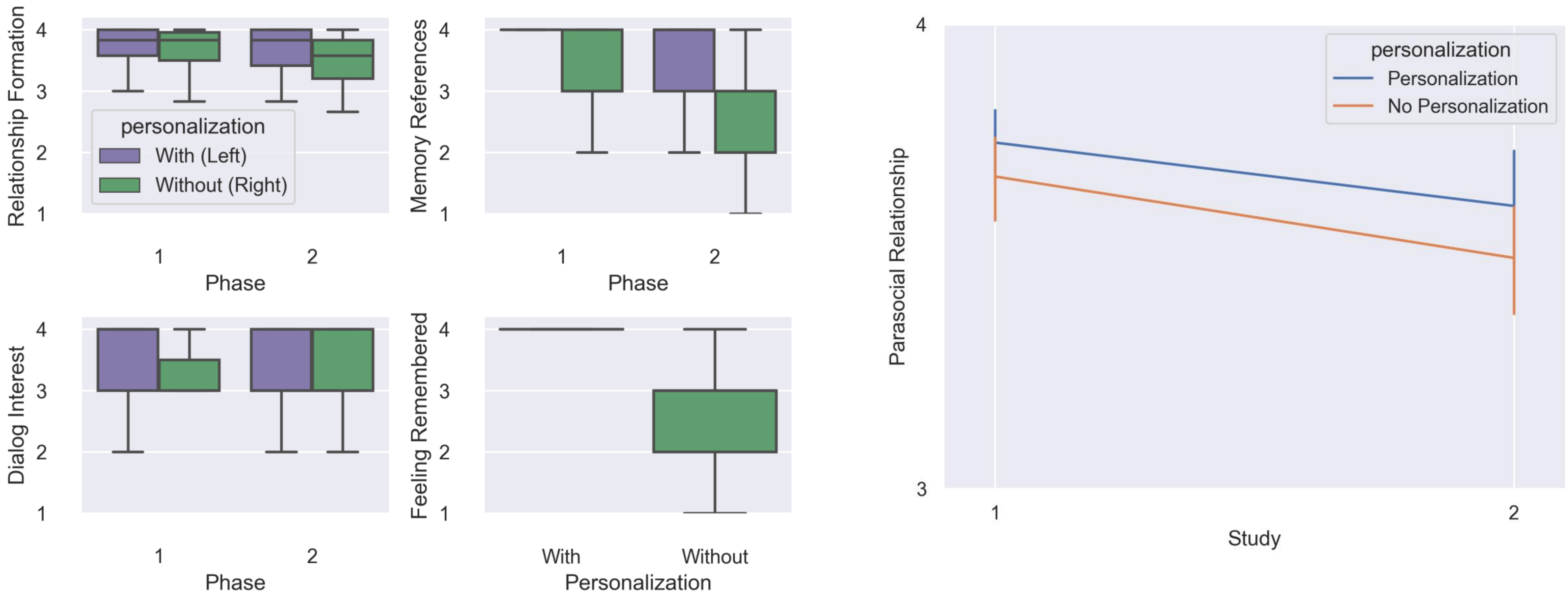
- Positive effect of **scaffolding** on math performance.

New hypotheses

- The act of guidance (including the second chance) boosted math efficacy which increased performance.



# Personalization



# Micro-assignment

- Read speculative scenario
- Highlight parts of the text you find meaningful and comment why.
- Submit .pdf on Canvas.
- Published later today.
- Deadline: Friday 23:59.