SIM

THE SOCIAL ROBOT

Designing for Affective Human-Robot Interaction

TEAM

NonVerbal

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Executive Summary

Robots have penetrated into our society at an astonishing rate over the past fifteen years. What started as machines performing repetitive tasks in manufacturing evolved into single-purpose machines for households tasks, and has more recently turned into dozens of different variations of robots that are aimed at a close integration into the daily life of the individual. Some prime examples would be the Roomba robotic vacuum, the Paro therapeutic robot, and intelligent software assistants such as Amazon's Alexa. The goal of our project is to re-examine our interactions with these technologies and also understand how we can design more natural and intuitive interactions.

From our extensive research, we found that people tend to have expectations for natural and social interactions with computers. They unconsciously treat computers like they treat real people, demonstrating politeness, showing concerns for their feelings, and even assigning intent, desires and personality traits onto machines. We synthesized an interaction model called the Social Interaction Model (SIM) that governs how a robot should respond to different scenarios like greeting new or familiar users, or completing a task. This model takes advantage of our existing knowledge of social interactions. We then developed a physical prototype of a table-top robot to evaluate our interaction model with users.

We compared two versions of our robot, one with the Social Interaction Model and one without. Our tests indicated that users developed a stronger affinity towards the social robot by personifying it and treating it like a living-thing. This indicates the success of our model in creating more natural and engaging interactions with robots.

Team

SAHIL ANAND

I'm a UX Engineer working in the field of robotics and computer vision. Currently, I'm in my second year of the HCDE Master's program at UW. I have experience building robots as well as designing software for Natural User Interface technologies. My particular expertise is in creating functional prototypes for testing new product ideas, features and concepts. I'm a self-taught programmer and an obsessive tinkerer passionate about learning. In my spare time, I enjoy experimenting with new languages and platforms in order to bring creative ideas to life.

JOHN LUETKE

I have a very strong technical background and am extremely passionate about user experience in the things I create. I have experience in the realm of robotics through the FIRST Robotics Challenge as both a student and mentor, and am absolutely enthralled by applications of technology to augment daily life, whether it be through AR, wearables, or by more natural interactions with technology. When I'm not being productive, and can be found binge-watching shows or playing video games.

NIKHIL VENKATASH

I have a strong passion for animation and interaction design, and come from a background in character animation and computer science. Animation relies heavily on studying how people interact with each other, how micro expressions and subtle body language nuances affect the dynamic between people. I believe that I can translate this knowledge to explore the possibilities and make Human-Robot interactions feel more natural. I love all things tech, and enjoy spending time discovering new technologies, playing with gadgets and thinking about the endless possibilities that the future holds.

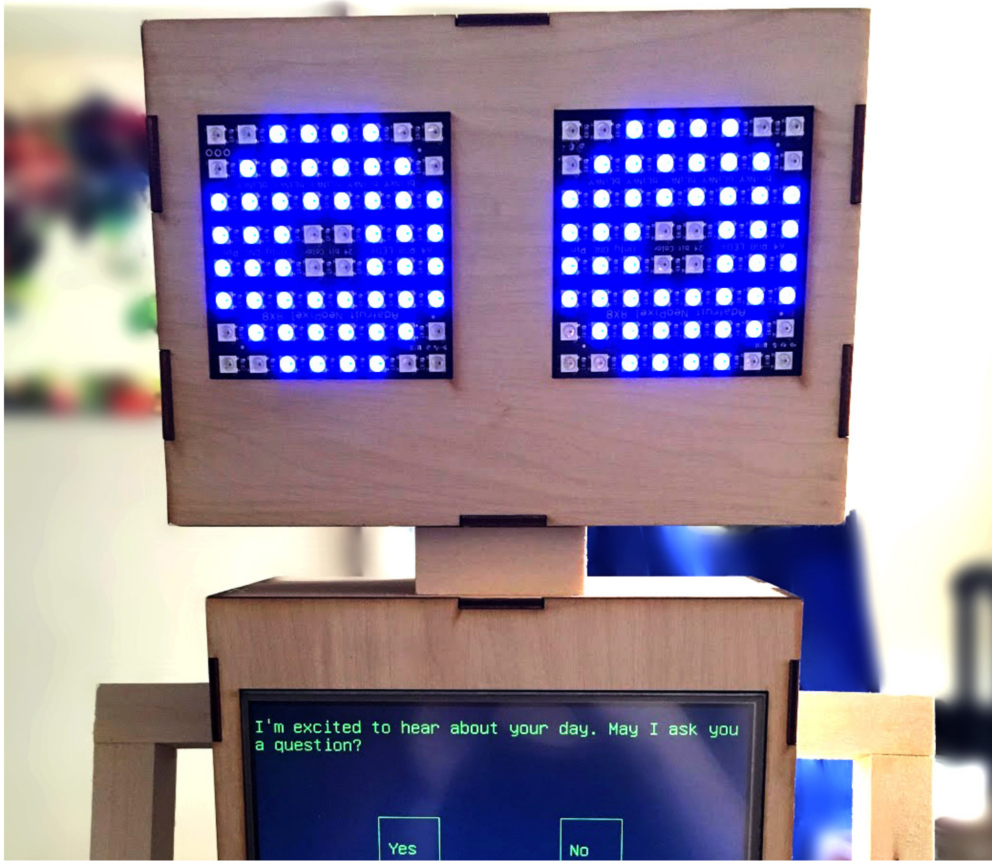
DOROTHY WONG

I'm a UX designer and project manager passionate about using my UX superpowers for making positive impacts. Currently, I am a second year grad student in HCDE at UW. I have a background in business before freelancing for a few years as a self-taught designer, working on various domains in technology. My strengths are in visual design, strategy, and being able to adapt quickly to new environments. I have a huge curiosity when it comes to futuristic tech and get excited easily by sci-fi movies involving space exploration!

INSPIRATION

The Idea

By and large, robots today are being used in very specific application settings. Some examples include robot-assisted surgery and therapy, milking cows in agriculture, and defusing bombs in the defense industry. These scenarios involve robots primarily interacting with trained professionals and performing very precise and specific actions. While the sensing, mapping, and navigation technologies that are needed by robots to be deployed in everyday public settings are mature, the social savvy-ness it takes to interact with humans is still in a state of awkward adolescence. As these robots enter our households and daily lives, the manner in which we interact with these technologies needs to be re-examined.



EMAR Case Study

In early 2016, Project EMAR was conceived at the University of Washington, Tacoma by Professors Elin Björling and Emma Rose. The overall objective of Project EMAR is to create a robot that can collect survey data “in the moment” from users.

As of December 2016, Project EMAR had undergone two prototype revisions. During testing of these prototypes, many users had trouble engaging with EMAR because its design failed to meet participants' expectations of how to interact: users attempted to speak and even touch EMAR’s embodiment when it was intended to be engaged by a touchscreen on its chest. Interestingly, participants immediately went back to perceiving EMAR as an object rather than a sentient being.

Related Work

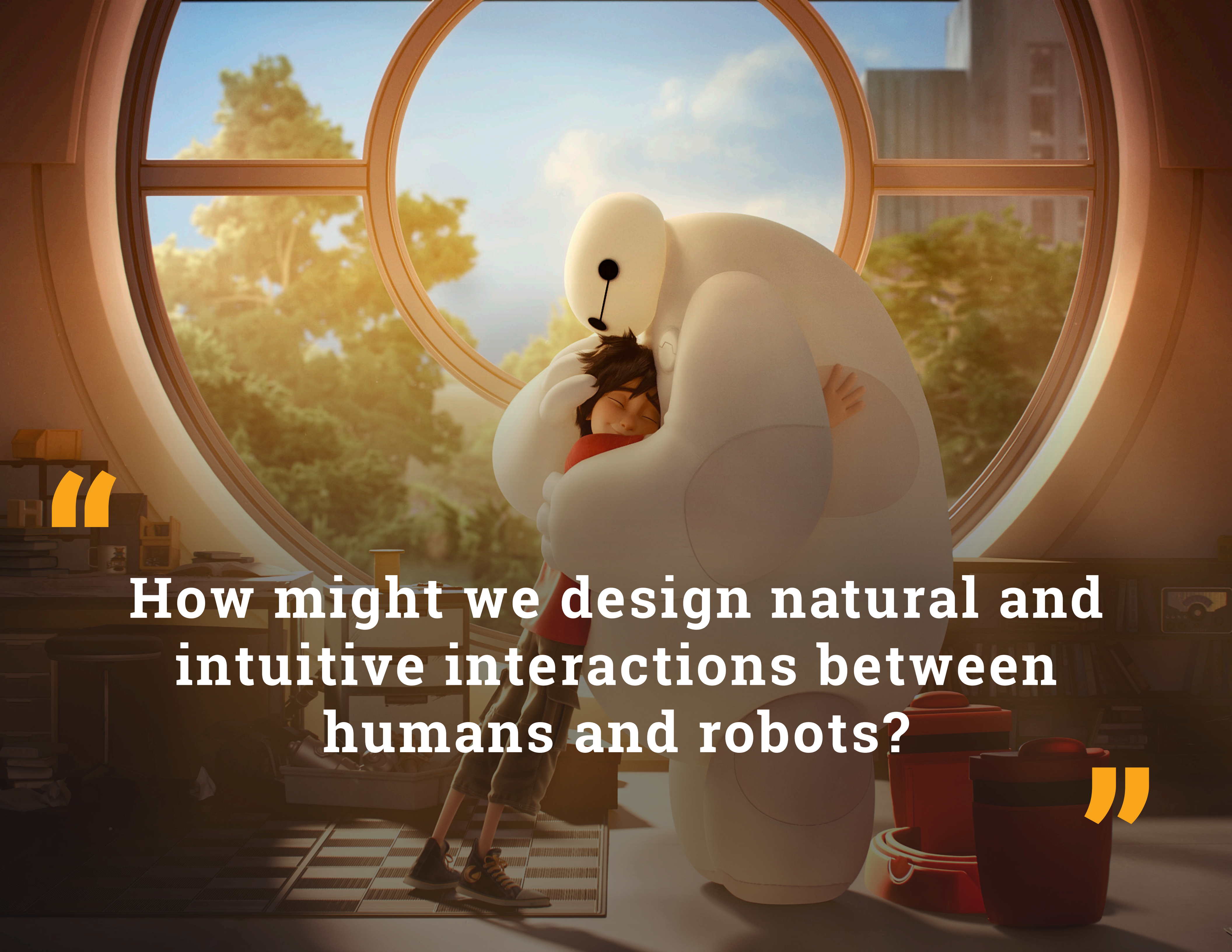
Other studies in the field of human-robot interaction suggest that accounting for simple social aspects in the design of robots improves interactions between humans and robots. In a study conducted with robot helpers in hospitals, researchers found that robots that abide by social norms not only reduce interruptions in workflow and social relationships, but also allow the robot to be perceived as a part of the intimate social environment, and therefore alleviate the resistance to use[1]. Robots capable of displaying social cues in the form of nonverbal behaviors during human-robot collaborative tasks attribute to improved task performance, higher recall accuracy, error prevention and faster task-completion times[2][3][4]. However an important limitation of using behavior generation models is that using too many nonverbal behaviors and inappropriate cues can be a hindrance to comprehension.

Another interesting study on ‘robotic trash cans’ by Yang[5] suggests that people naturally attribute intrinsic motivations and desires to a robot’s behavior, which in turn encourages them to interact with the robot in social manner. For example, researchers observed participants initiating interactions and disengaging with the robot using gestures, and described their experience of attracting the robot and throwing away trash as ‘feeding the robot’. A few individuals even treated the trash barrel as they might a pet. Others who were busy simply ignored the robot or showed hesitation. This study was carried out at a public eating area of a university campus in San Francisco. As social interactions are context-dependent, it is possible for people to perceive the robot differently under different contexts, like at a theatre or at an airport. A study with the robots under diverse social and cultural environments could reveal more insights into human-robot interaction.

Solution

On the whole, our research indicates that people have social expectations for interactive robots. This is consistent with Reeves and Naas’ Social Response to Communication Technology hypothesis that people engage with computers and automated technologies socially, and derive emotional responses much like the way they would with human interactants[6]. Thus, robots integrating into households must, in addition to physical assistance, provide mental and emotional assistance as well. The commercial success of these robots hinges not only on their utility, but also on their ability to maintain rich, long-lasting relationships with members of the household.

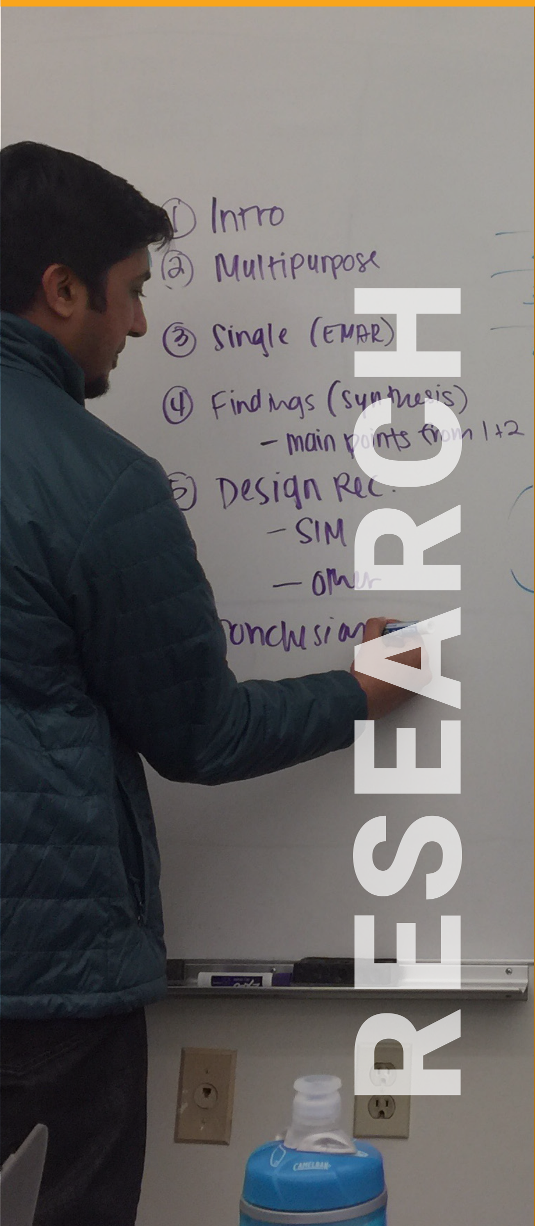
Research indicates that for establishing compelling social interactions and long-term relationships, robots will need to engage in rich, affective interchanges with humans[7]. Humans communicate with each other using a wide range of verbal and non-verbal behaviors like gestures, facial expressions, gaze, and body language. The expressive characteristics of non-verbal behaviors serves an important function in communicating emotional state to others. This benefits people in two ways: first, by communicating feelings to others, and second, by influencing others’ behavior[8].

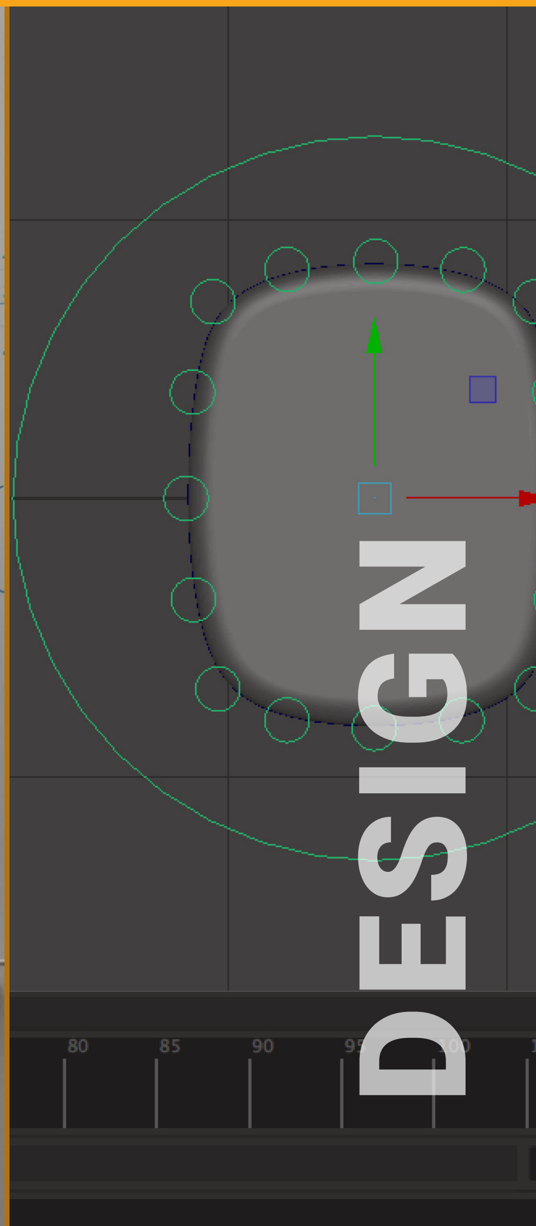

"How might we design natural and intuitive interactions between humans and robots?"

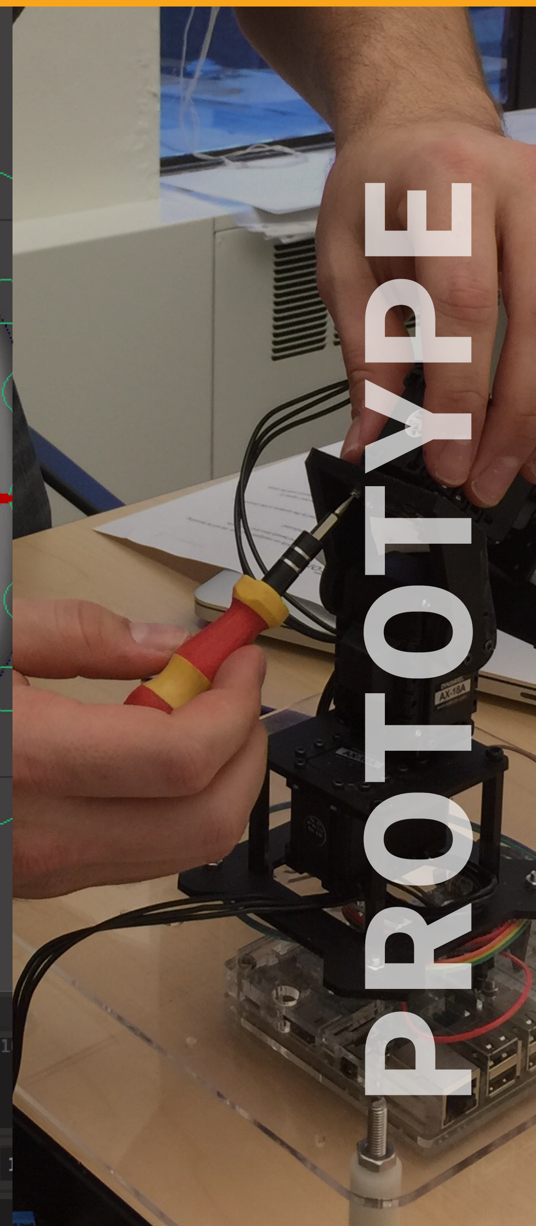
Introducing SIM

Using these findings, we created SIM, our prototype of a socially intelligent robot. SIM can engage in affective interchanges with humans by understanding and expressing emotions. Its behavior is governed by the ***Social Interaction Model (SIM)*** *that we have synthesized from our research. We believe that socially intelligent robots can afford more natural and intuitive interactions with humans.*

DESIGN PROCESS







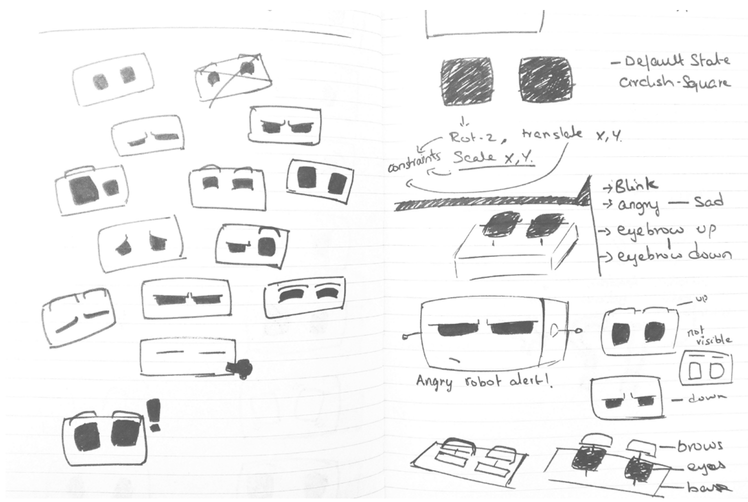
The Social Interaction Model (SIM)

Our Social Interaction Model (SIM) presented below is a set of rules inspired by theories of emotions in human beings that govern how our robot will respond to different environmental stimuli. It is adapted from Cynthia Breazeal's work on 'Kismet', a robot designed with the social competency of a human infant[7]. The table below summarizes the antecedent conditions, example scenarios, behavioral responses and the functions they serve the robot. It is based on the evolutionary, cross-species, and social functions hypothesized by Plutchik[9][10], Darwin[11] and Izard[12].

Antecedent Conditions	Emotion	Behavior	Function	Example Scenario
Delay, difficulty in achieving goal of adaptive behavior	anger, frustration	display displeasure	Show displeasure to user to modify his/her behavior	The robot spends too long on a task, or is unable to achieve the desired outcome within a reasonable amount of time
Presence of an undesired stimulus	disgust	withdraw	Signal rejection of presented stimulus to user	Robot is encouraged to violate Asimov's First Law of Robotics.
Presence of a threatening, overwhelming stimulus	fear, distress	escape	Move away from a potentially dangerous stimuli	A user screams or otherwise elevates their voice at the robot, or suddenly decreases the distance between themselves and the robot.
Prolonged presence of a desired stimulus	calm	engage	Continued interaction with a desired stimulus	Robot maintains a continued positive interaction with a user.
Success in achieving goal of active behavior, or praise	joy	display pleasure	Reallocate resources to the next relevant behavior (eventually to reinforce behavior)	Robot completes an interaction with a user after a time of absence, robot is praised by the user.
Prolonged absence of a desired stimulus, or prohibition	sorrow	display sorrow	Evoke sympathy and attention from caregiver (eventually to discourage behavior)	Robot is unable to initiate or participate in an interaction with a user for a sufficiently long period of time.
A sudden, close stimulus	surprise	startle	Alert	A drastic change in one or more low level sensory inputs, like fast movements in the robot's field of view, sudden loud noises,etc.
Appearance of a desired stimulus	interest	orient	Attend to new, salient object	A new user enters the robot's field of view
Need of an absent and desired stimulus	boredom	seek	Explore environment for desired stimulus. Failure leads to sorrow	Robot does not begin a new interaction after completing another interaction within a short, given period of time.

One of our earliest questions was "*how far do we want to go when building a physical prototype?*" We quickly discovered that the term "robot" conjures many different images and ideas, especially around the subject of mobility.

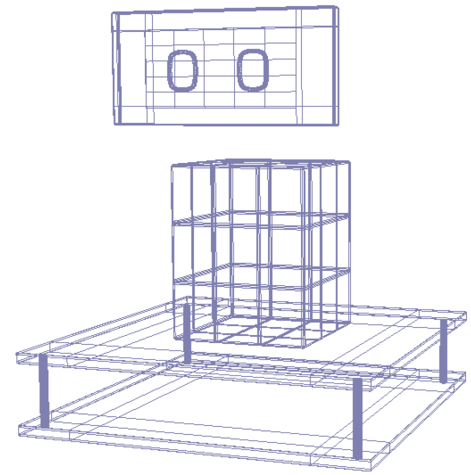
Given these nebulous set of expectations and ideas, and a constraint of ten weeks, we chose to make SIM non-mobile.



Facial Design

Eyes play a significant role in the dynamic of a social exchange between people: their expressions can instantly set or change the tone of an exchange. SIM has a simple face, consisting of just a pair of flat-colored rounded rectangles that serve the role of eyes. These eyes are designed to mimic human eyes in order to help people read and understand SIM's emotions. However, they are exaggerated in both size and motion, similar to a cartoon character.

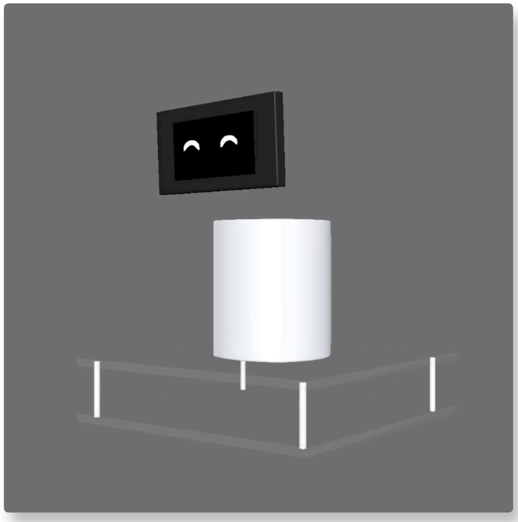
We were inspired by Disney's 12 principles of animation to make the animation feel organic. By using principles like squash, stretch, and arcs, SIM's motions feel more natural and smooth. By exaggerating SIM's eyes, we are able to compensate for the lack of other facial features, and also avoid looking "too human" which could make some people feel uncomfortable.

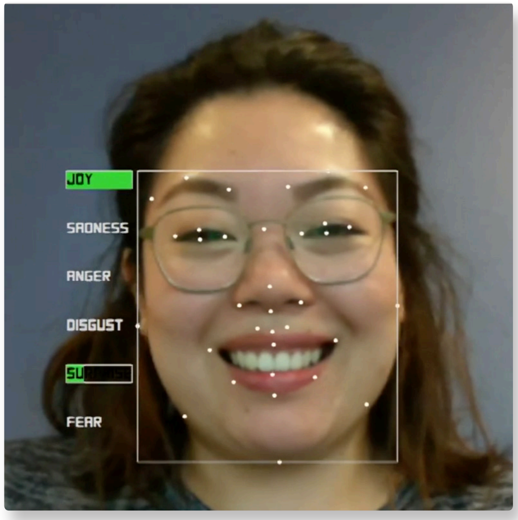


The Rig

SIM's body needed to be constrained to only move as much as the physical motors could: we had to build constraints within the rig to lock rotations between certain angles. This ensured that we could create animations without having to worry about whether it would mirror properly on the physical prototype.

For the face, we needed to have enough flexibility to express extreme emotions. This meant adding more levels of control to provide finer adjustments for the shapes, and pre-defined shapes for common emotions. To add some variability and randomness, the rig has one additional control which can be used to modify the predefined shapes.





Animation

We constructed 8 virtual animations to test SIM's emotional expressions. This test was distributed electronically and was completed by 69 respondents.

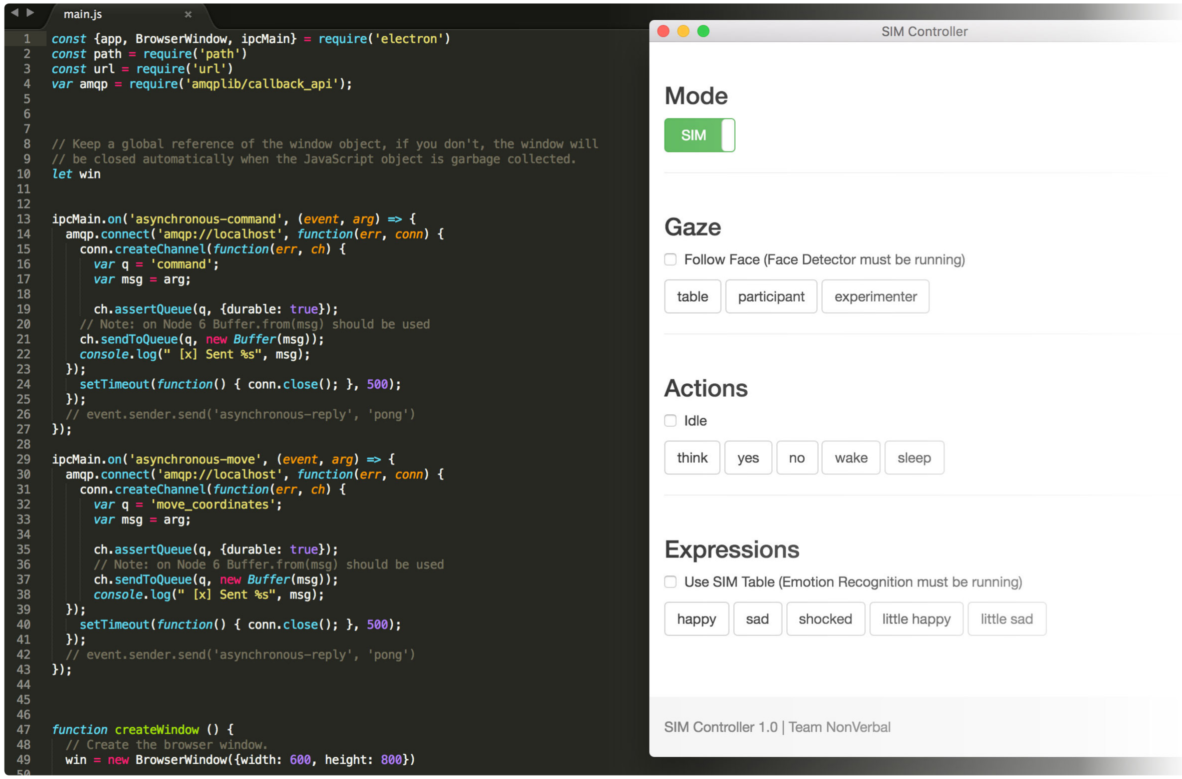
Each emotional expression was identified accurately by the majority (between 49.3% and 88.4%) of survey respondents. For the four expressions that scored below 70%, we iterated and tweaked the animations.

Physical Embodiment

SIM's body is composed of three servo motors, providing two yaw rotations, and one pitch rotation. This configuration allows SIM to achieve simple expressions like "yes" and "no", as well as the ability to orient itself towards the user.

Emotion Recognition

SIM is able to recognize a user's emotion through software produced by Affectiva. This software captures an image of the user's face, processes it, and provides a list of emotions detected, as well as a confidence score for each emotion. We use the highest scoring emotion as an input to our Social Interaction Model.



Control

SIM is primarily controlled by observing the user, and responding to the facial emotions being displayed by a user. It can also be controlled by a "Wizard of Oz" technique through a dashboard interface on a computer.

The dashboard is divided into three sections: gaze, actions, and expressions, each of which control a separate reaction for SIM.

Gaze dictates where SIM is actually "looking". It primarily controls the second yaw servo, allowing SIM to "look" left or right. With "face tracking" enabled, SIM can identify the primary face in its view, and orient itself to always be looking at that face.

The "Actions" section controls independent actions that SIM can take.

"Expressions" controls how SIM responds to stimuli from the user. These responses are powered by our Social Intelligence Model, but can also be triggered manually.

EVALUATION

Test goals

The primary goal of testing was to evaluate the Social Interaction Model with users using the physical prototype. We compared two version of the robot, one with the Social Interaction Model (SIM) and one without (DUM).

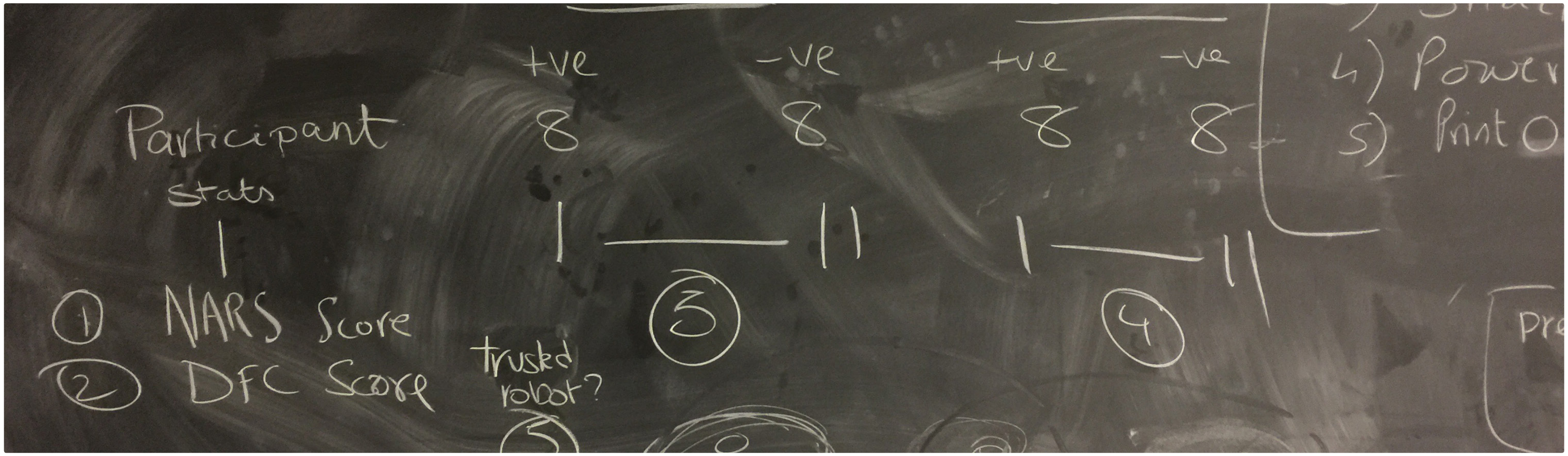
Participants were asked to team-up with the robot in both conditions and perform a series of tasks. The tasks were designed to measure whether participants would trust a robot when they were faced with uncertainty during a decision-making task.

We relied on trust as a predictor of long-term relational success between humans and robots as trust has been increasingly employed to assess the quality of human-robot interactions[13], and is considered a valid indicator of robot's functional and social acceptance[14].

We also measured the frequency and intensity in which participants praised or punished the robot for its contribution towards each task. This served as an indicator of participant's satisfaction or frustration with the robot.

We investigated the extent to which negative attitudes towards robots and a personality trait called Desire For Control can be considered as factors influencing the robot's acceptance using existing surveys from literature - Negative Attitude towards Robots (NARS)[15] and Desire for Control (DFC)[16].

We also observed the quality of interactions between the participant and the robot. Each session concluded with an interview to understand how participants compared their experience interacting with each version of the robot.



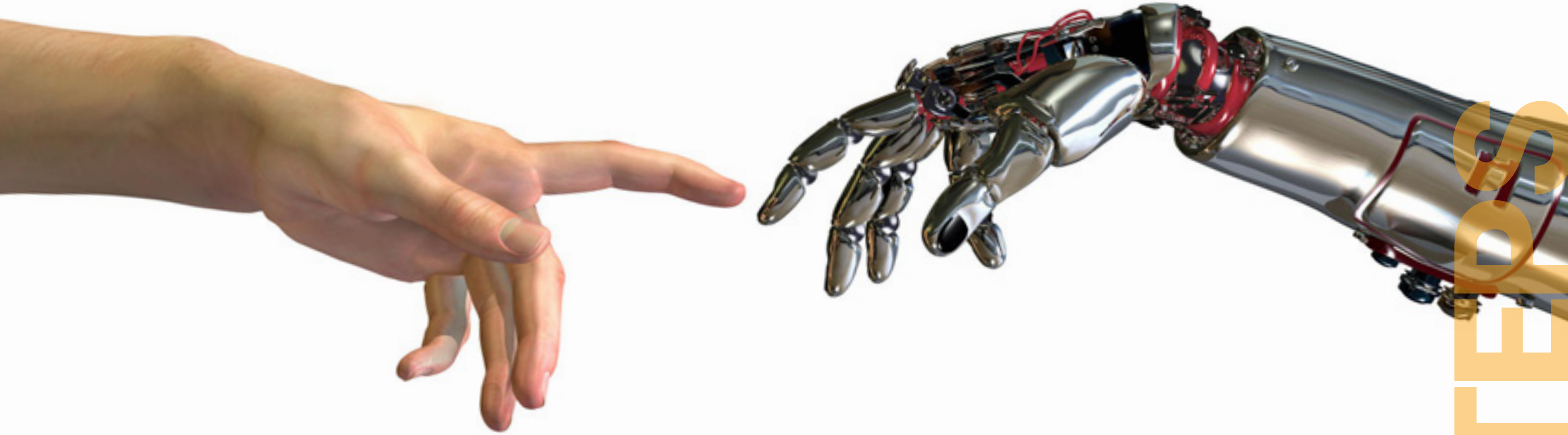
Findings

- No conclusive results were found to demonstrate that participants trusted the robot in the SIM condition more than the robot in the DUM condition. Users trusted the robot in both conditions equally.
- 4/5 participants punished the robot with lesser intensity (low negative scores) in the SIM condition compared to the robot in the DUM condition when the robot provided the wrong answer. For the remaining four participants, the moderator did not correctly reveal the answer, so we excluded those sessions from this finding.
- Users personified the robot in the SIM condition, using adjectives like fun, friendly, happy, helpful, thoughtful, considerate, interactive and entertaining to describe it.
- Participants with DFC scores below 100 appeared to trust the robot more, changing their answers an average of 3.83 times throughout the course of the study. In contrast, participants with DFC scores above 100 changed their answers an average of 2.66 times.
- Participants surprisingly made an assumption that the intensity of SIM's expression while agreeing or disagreeing with them on a task correlated with the strength of its opinion. However, this was not initially intended in our designs as SIM randomly chose an intensity of expression for each task.
- Based on the average number of changes between genders, females tended to change their answers more (3.8, compared to 3.0 for males), but the standard deviation (1.23) was too high for this analysis. Therefore, we cannot draw any definitive conclusions from this data.
- No significant results were found to demonstrate any correlation between participant's NARS score and their trust in the robot.
- 4/9 users tried engaging in conversations with the robot seeking justification for disagreements during tasks or friendly banter, despite being told that the robot did not have a voice and could not communicate verbally.

THE ROAD AHEAD

NEXT STEPS

One of the largest obstacles we faced was the limited time frame we had to accomplish this project. After scoping down at least twice, we accomplished enough to prove that rich, affective interactions create more engaging Human-Robot Interactions. Of course, there is plenty of additional work to accomplish in the future.



Project Trajectory

We sought out to make SIM an engaging and interactive character. However, we did very little work in the space of giving SIM a personality. We believe that developing an innate set of desires, goals, and other assorted behaviors will create a more rounded and believable character. Integrating this personality into the Social Interaction Model will allow our research to be applied more effectively.

Once a personality is defined, the facial animations and body motions can be improved to make SIM more expressive. By adding a greater variety of expressions, we can portray a more realistic personality for SIM.

Personality can also move beyond how SIM acts and be projected onto how it looks. Our prototype has many exposed technical facets, such as the wires and servos, creating a distinct machine-like appearance. In the next iteration, we hope to create the perception of a polished and complete character.

Reflections

During the capstone showcase, we had somewhat of an epiphany. We observed that nearly every person who came to “meet” SIM displayed no confusion as to whether or not it was interacting with them. When they stepped in front of SIM, it responded immediately by looking at them. No one tried to touch it to activate it, like a typical machine. However, a few people did try to engage with speech, a facet of the project that we intentionally dropped from our scope. On this piece of evidence alone, we managed to prove that a robot possessing basic social intelligence such as gaze orientation can make initial interactions more seamless and natural.

The formal usability tests we conducted lacked in both the number of participants and tasks. As previously mentioned, the nine participants failed to show us any significant trends in finding a strong correlation to prove 2 of our of 5 hypotheses. While the qualitative data we collected indicated that our project was a success, the inherent subjectivity of that data leaves more quantifiable proof to be desired. Our testing tasks were specifically designed to test whether the user would begin to trust the robot over time, laying the foundation for a long-term relationship. There are a number of indicators for determining a successful long-term relationship, such as engagement, disclosure, and expectations. But for the purpose of the study, we decided to measure trust and acceptance in order to avoid exhausting our participants with a multi-hour session.

Lastly, the participants involved in the HRI studies that we have both reviewed and conducted have had very little personal experience with everyday robots. Interacting with a robot is a novel experience for most people. Since the technology is still at a nascent stage, people have different expectations from robots. It is possible that these expectations are driven by robots portrayed in popular science fiction books and films. Repeated exposure to robots in daily life may alter these expectations and norms of interactions. Thus, a longer term study involving many different types of robots and a larger number of participants will help shed light on how the relationship would evolve over time.

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Thank you!