USC Interaction Lab & CSULA XP Lab
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Communicate, Share, Adapt: A Mixed Reality Framework for Facilitating Robot Integration and Customization

PIs: Maja J. Matarić, David M. Krum **Award #:** IIS – 1925083
PhD Students: Thomas R. Groechel, Amy O'Connell, Zhonghao Shi, Chris Birmingham
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Learn more on our NRI 2.0 grant website: https://tinyurl.com/NSF-SVTE

NSF

Objective

Develop a Shared Virtual Teaching Experience (SVTE) to leverage the immersive interaction potential of virtual and augmented reality (VR and AR) to: teach users how to communicate with robots, build user-robot rapport through sharing, and adapt robot behavior for real-world interactions based on the training from the immersive experience. Validate with older adults & youth.

Background and Motivation

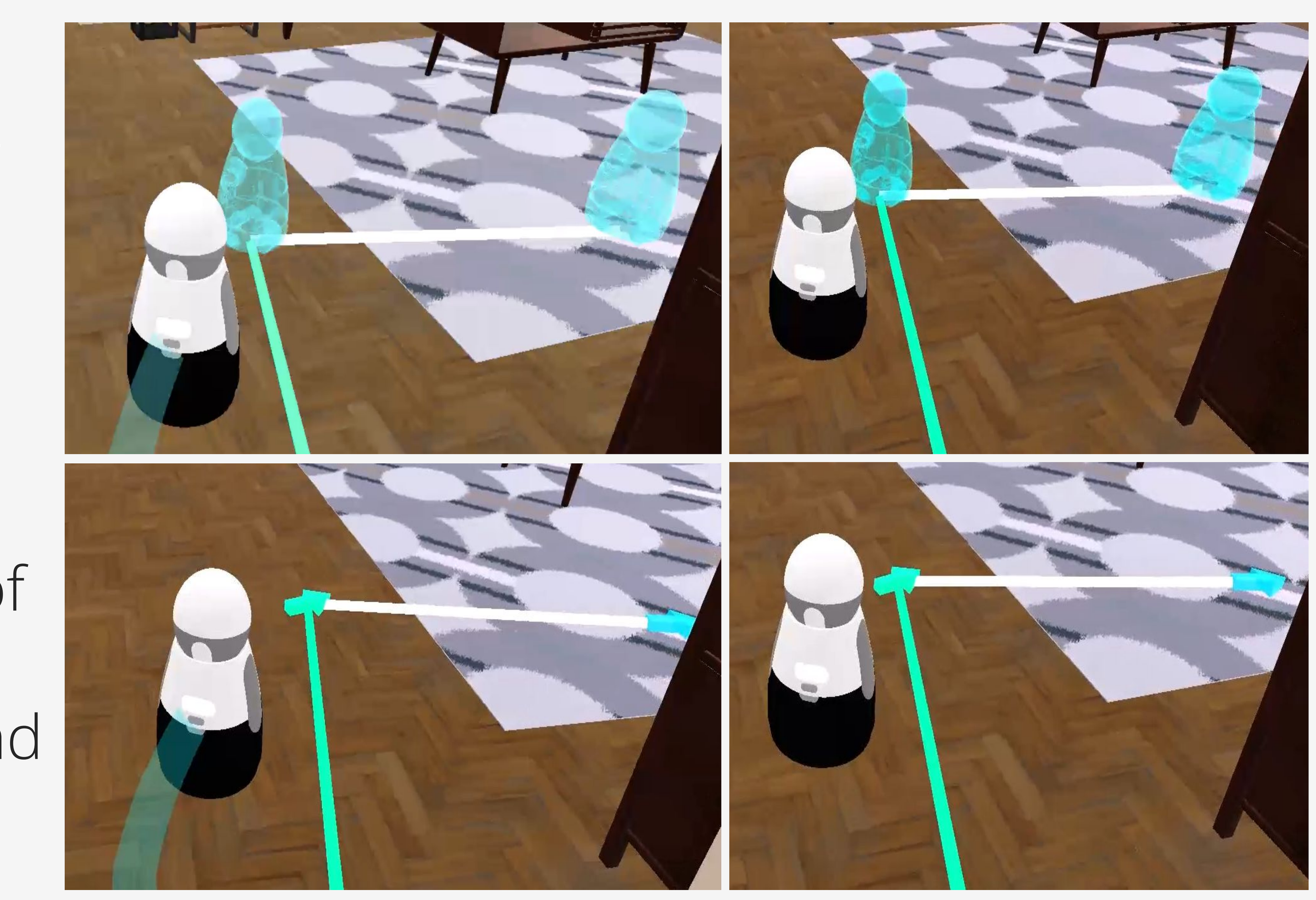
- Research has consistently found that older adults are open to using robots as companions, but that they want robots to perform at the level of a human caregiver, specifically in ways that require more advanced social skills [1].
- The significant need for personalized integrated co-robots for the rapidly growing elderly population requires natural bi-directional communication, but key barriers include limited perception and signaling affordances of robots [2].
- Users do not understand robot limitations, leading to frustration and abandonment of co-robots [3].
- Using immersive technologies to enable non-experts to communicate in HRI contexts has shown promise; studies have explored showing users camera views from the robot [4] and natural deictic gestures [5].
- A key challenge for human-machine interaction in general and HRI in particular is *personalization* to the user [6], where the data-rich environment of mixed reality can be exploited.

SVTE Interaction Setup

Users participate in the SVTE by engaging in a collaborative task with the robot. During the SVTE, a head-mounted display (HMD) projects virtual imagery onto the real world to signal the capabilities of the robot to the user.

Signal Design

To create visualizations that effectively convey these capabilities, we identified key characteristics and salient Virtual Design Elements (VDEs) for AR signaling of core robot capabilities (e.g., navigation, audio localization). Signal designs were informed by design interviews with older adults, prior visualization research, and existing visualization software.



Navigation visualizations varied by waypoint and trail VDEs

User Study Results

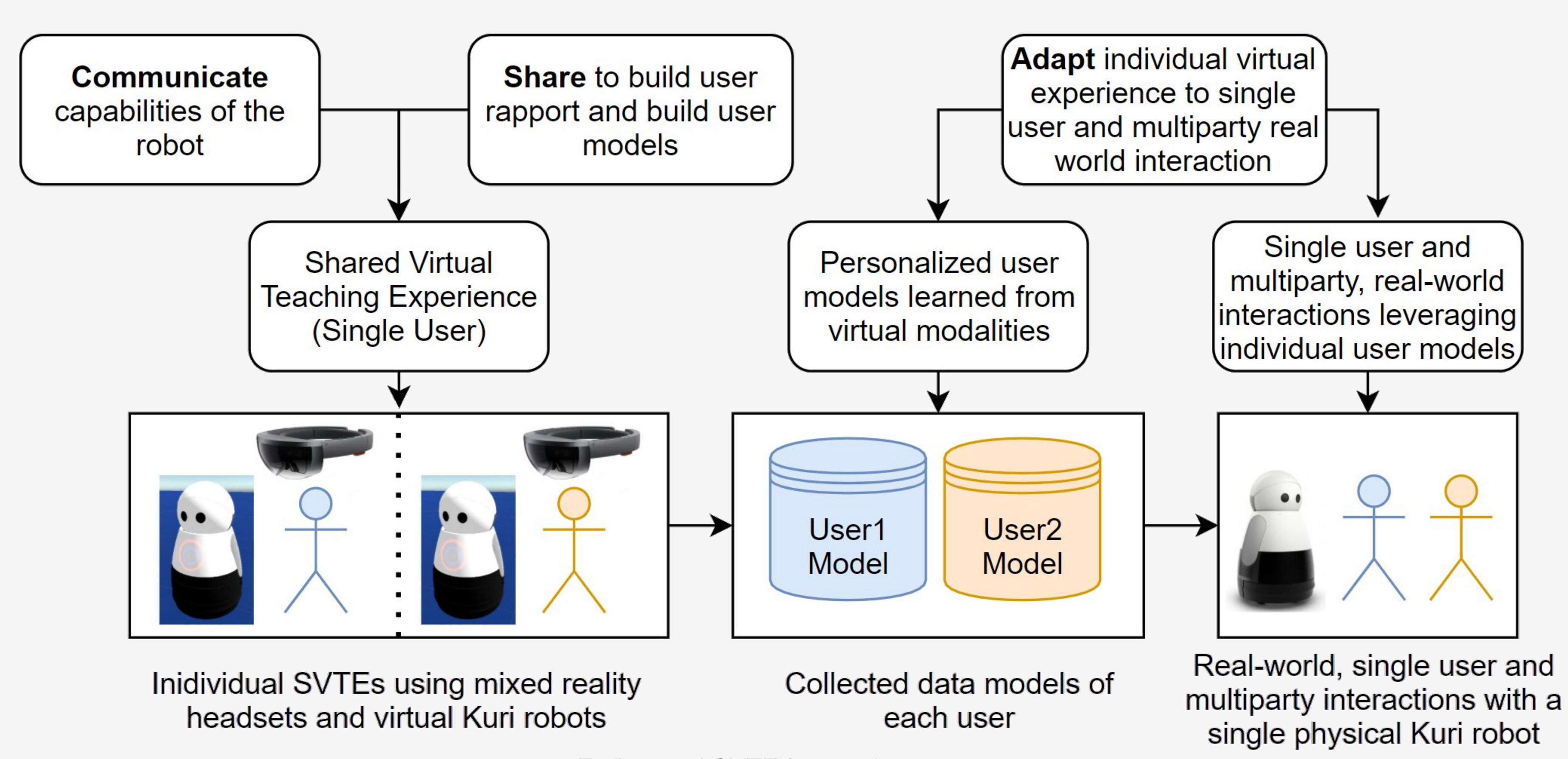
Using Amazon MTurk we deployed a within-subjects study (n=150) in which non-experts answered questions about six sets of signal visualizations. The participants were asked about their preferences for each signal visualization, and prompted to offer suggestions for improvement. For example, a participant assessing the navigation signal design gave the following feedback: "Before the robot moves, there should be a small thought bubble with a travel plan." The results define a set of the most clear and visually appealing signal visualization designs and inform about interaction effects among VDEs to be considered in future AR designs.

Audio localization visualizations

Face detection visualizations

Ongoing Work

We are transferring user models learned in the SVTE to real-world interactions. We are working with our partner institution Front Porch to conduct an SVTE validation study in a retirement community in Los Angeles.



End-to-end SVTE Interaction

Outreach

- 2021 Virtual Robotics USC Open House talk and mixed reality demo on showcasing this work (~50 people).
- "PoseToCode: Embodied Learning for Coding" outreach activity with local Los Angeles 5th grade class (24 students) as a part of USC CS Ed Week. Online demo: https://posetocode.web.app/tutorial.html
- "Human-Robot Interaction & Socially Assistive Robots" talk at Laguna Woods Village elder care facility (~70 people).
- "What is a Socially Assistive Robotics Ph.D.?" virtual talk for Temple City High School (~20 people).
- 2020 Virtual Robotics USC Open House talk and mixed reality demo on showcasing this work (~50 people).
- Family Robotics Night demos as Monterey Hills Elementary School showcasing MR robotics (~50 people).
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References

[1] Bedaf, Sandra, et al. "Can a service robot which supports independent living of older people disobey a command? The views of older people, informal carers and professional caregivers on the acceptability of robots." *International Journal of Social Robotics* 8.3 (2016): 409-420.
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[3] Ishak, Danielle, and Dan Nathan-Roberts. "Analysis of elderly human-robot team trust models." *Proceedings of the Human Factors and Ergonomics Society* Annual Meeting. Vol. 59. No. 1. Sage CA: Los Angeles, CA: SAGE Publications, 2015.
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[6] Lee, Min Kyung, et al. "Personalization in HRI: A longitudinal field experiment." *Proceedings of the Seventh Annual ACM/IEEE international Conference on Human-Robot Interaction*. ACM, 2012.

Everything below this is prior year slides/work

Visualizing Robot Capabilities using Augmented Reality: Designing with Co-Dependent Factors

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Objective

Identify key characteristics and design considerations for specific signals when creating augmented reality robot signals for non-expert users. Design a shared virtual teaching environment t for older adults to increase knowledge of and comfort around robotic companions.

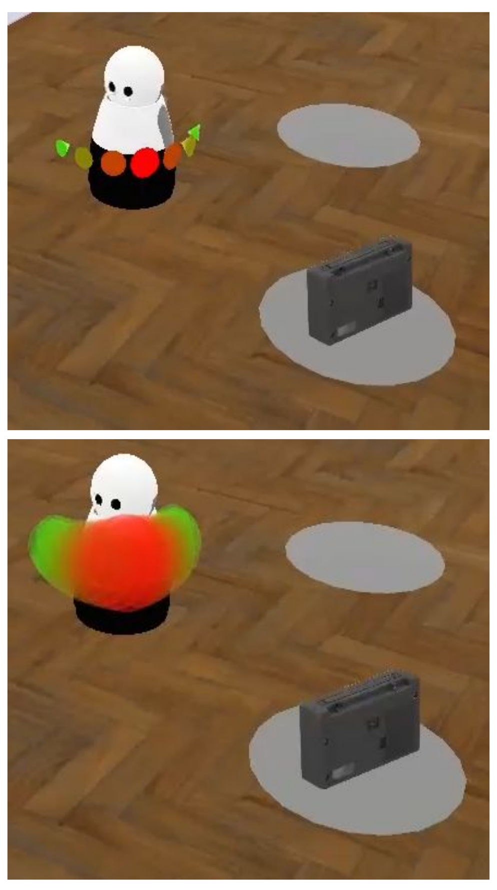

Figure 1

Background and Motivation

- Research has consistently found that older adults are open to robots as companions, but that they want robots to perform at the level of a human carer, specifically in ways that require more advanced social skills. [1]
- The significant need for personalized integrated co-robots for the rapidly growing elderly population requires natural bi-directional communication, but key barriers include limited perception and signaling affordances of robots. [2]
- Users do not understand the limitations of robot communication and cognition, often leading to frustration and abandonment of co-robots. [3]
- Robotic simulation software, such as RViz, offers a variety of visualizations to convey common robotic capabilities
- These visualizations were created by experts for experts, without regard to validated design principles or understandability of non-expert users
- Little prior work has investigated the most salient characteristics of the visualization design for maximizing understanding, especially for a non-expert audience

Design Set Up

Users be doing everything in Amazon Mechanical Turk. Each signal design has two differing factors. For example, above you see a visualization for directional audio (Fig. 1). The factors include the shape (cones or spheres) and scale of the shape (governed by: $\forall$ *m in mic[],* $m_{scale} = x_{max} * [(x - x_{min}) / (x_{max} - x_{min})]$ *for max = 2.5 | 1).* To the right (Fig. 2) you can see a navigation visualization with the factors of (3D outline/arrow & trail/no-trail). Below (Fig. 3) you see face detection with factors of (square/mesh & in 3D/only HUD).

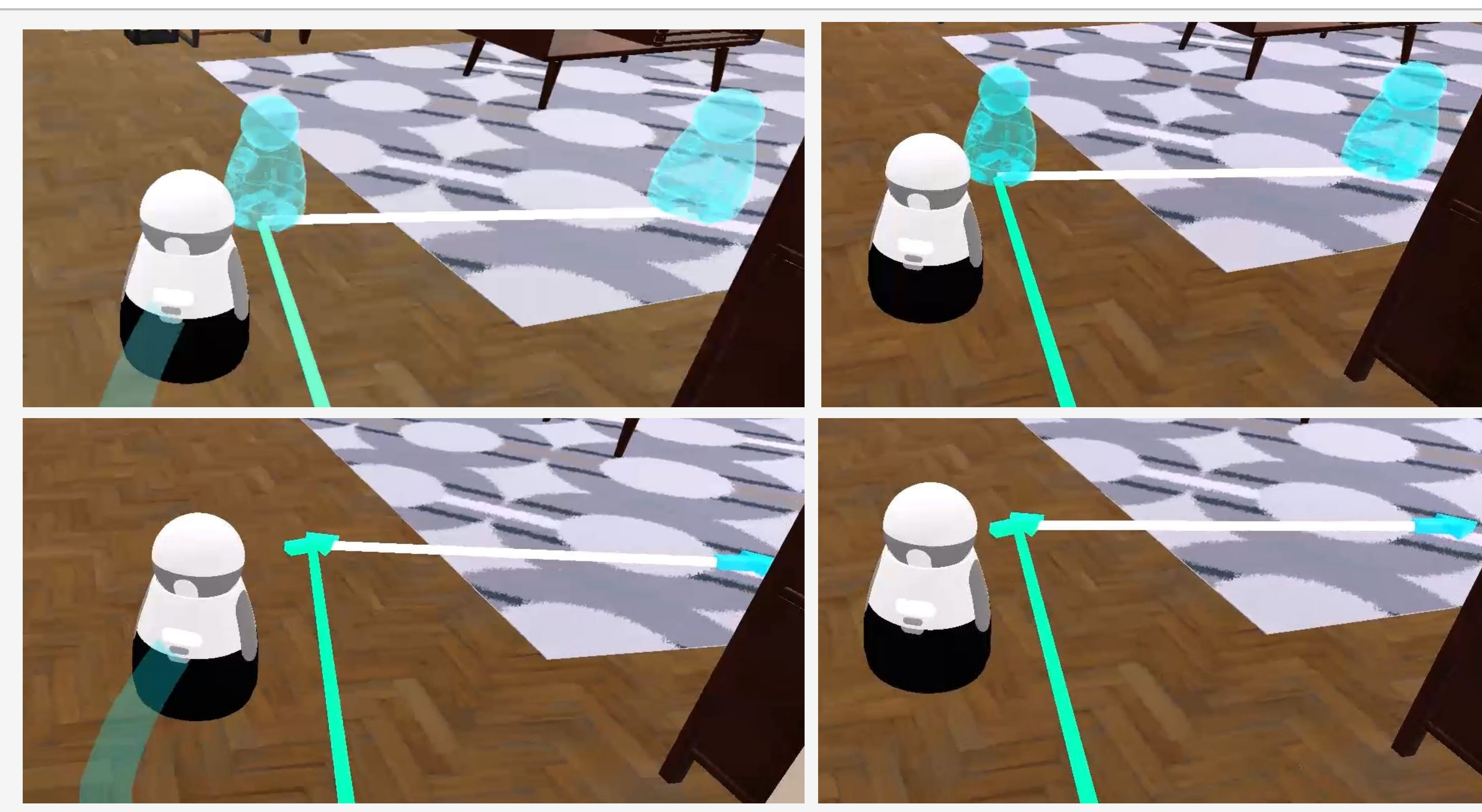

Figure 2

Potential Results

A difficulty with A/B testing is the idea that you have isolated for all cofactors. We will potentially see this fault if people rank paired designs that have no overlap as the best two signals. This is a similar effect described within a talk about pasta sauce preferences (there is no 1 perfect amount of sugar as it depends on other factors of the sauce).

We hope to use the ratings of the visualizations to justify preferences learning. If there are clusters of ratings across designs, we plan to quickly learn user preferences in future studies quickly and show those preferred group of visualizations.

Figure 3

References

[1] Bedaf, Sandra, et al. "Can a service robot which supports independent living of older people disobey a command? The views of older people, informal carers and professional caregivers on the acceptability of robots." *International Journal of Social Robotics* 8.3 (2016): 409-420.

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POSTER REQUIREMENTS:

All PIs of active NRI and FRR projects, including those in NCE, should prepare one poster per project whether it be a collaborative or independent. Each poster will be assigned to one poster session, meaning that, if a PI has more than one award, each will require a separate poster. A schedule of the posters per session has been posted at: https://cps-vo.org/group/nri-pimtg21/poster-sessions.

- Posters should explain research by all collaborators and note all award numbers, institutions, and names of PIs/Co-Ps. The lead PI or alternate(s) for each project is responsible for submission of electronic copies via the **"Submit Poster"** tab or at https://cps-vo.org/group/nri-pimtg20/submit-poster no later than **11:59pm on Friday, February 26, 2021**.

Posters will be uploaded into Gather.town by the meeting organizers. The electronic versions will be posted to the website. **The electronic copy must be submitted in PDF file format.**

Templates for posters can be found at: https://cps-vo.org/group/nri-pimtg21/poster-template.

All PIs who wish to submit video demonstrations of their projects are encouraged to do so. Demonstration participation is optional. Demonstration information can be entered at the poster submission link at https://cps-vo.org/group/nri-pimtg20/submit-poster and are due by **Friday, February 26, 2021.**

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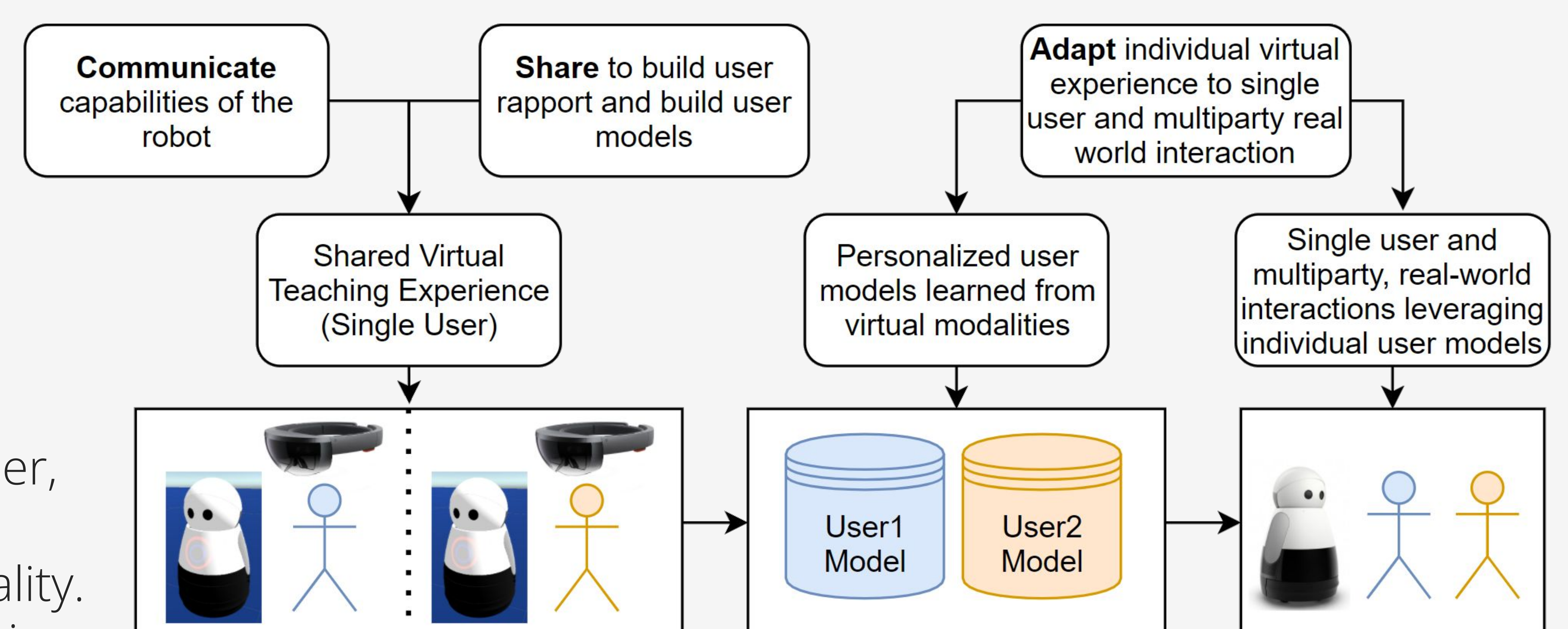
SVTE Interaction Setup

Users first take part in the SVTE in a head-mounted display (HMD), engaging in a collaborative task with the robot. The user model obtained from the virtual experience is then transferred to the physical robot for one-on-one and multiparty interactions.

Real World Model Transfer

During the SVTE, the robot develops a model of the user, consisting of the user's understanding of the robot's capabilities and details of the user history and personality. We explore how the robot can make use of the model in the physical world to improve the quality and effectiveness of one-on-one and multiparty interactions.

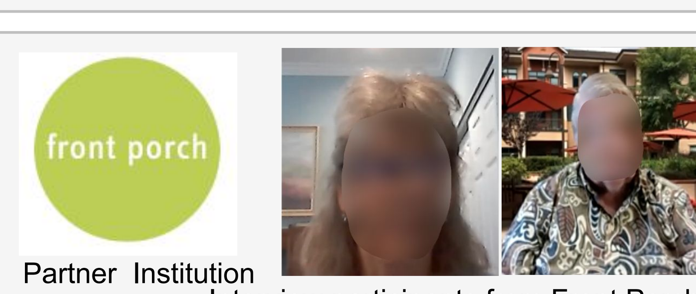


Inidividual SVTEs using mixed reality headsets and virtual Kuri robots

Collected data models of each user

Real-world, single user and multiparty interactions with a single physical Kuri robot

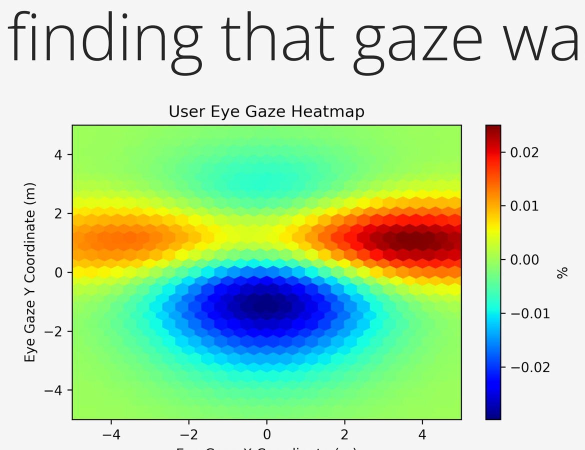
Results To Date



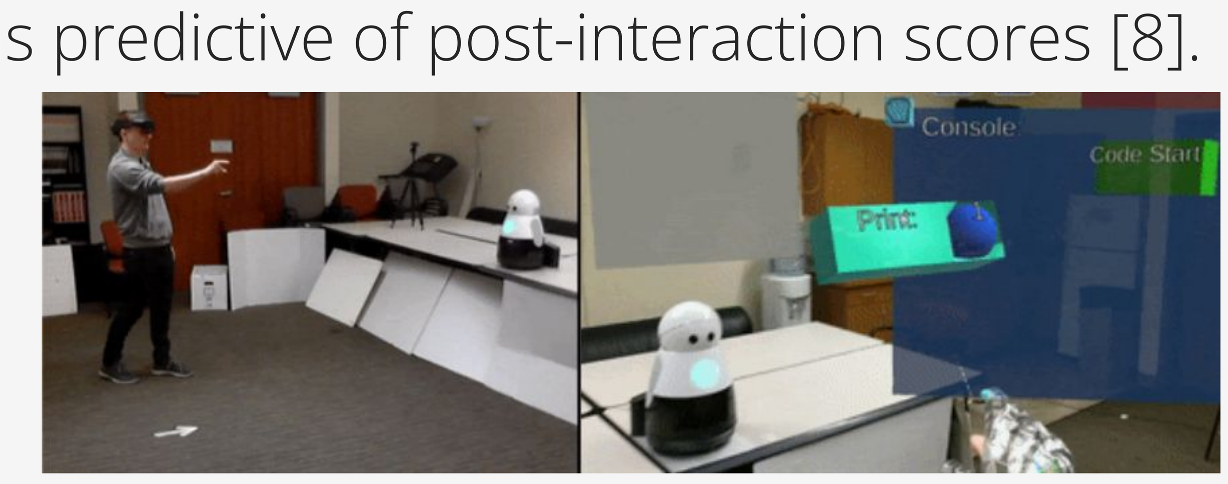
Partner Institution

Interview participants from Front Porch

Conducted design interviews with older adults aged 75 to 87 at the Front Porch retirement community in Los Angeles. Conducted a user study that tracked and scored different data modalities from the MR headset worn by students completing coding exercises within MoveToCode [7], a block-based visual programming language we developed. We analyzed the behavioral data for correlations with usability survey data, finding that gaze was predictive of post-interaction scores [8].



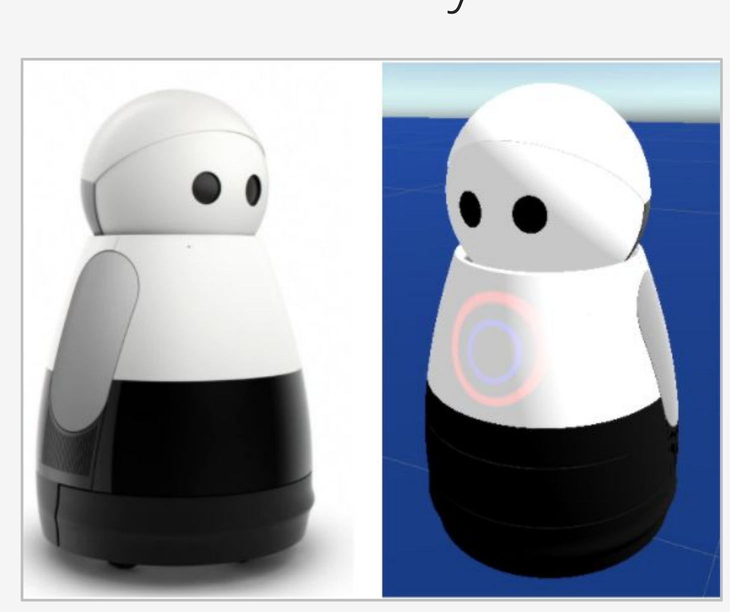
Eye Gaze heat map data from MoveToCode study

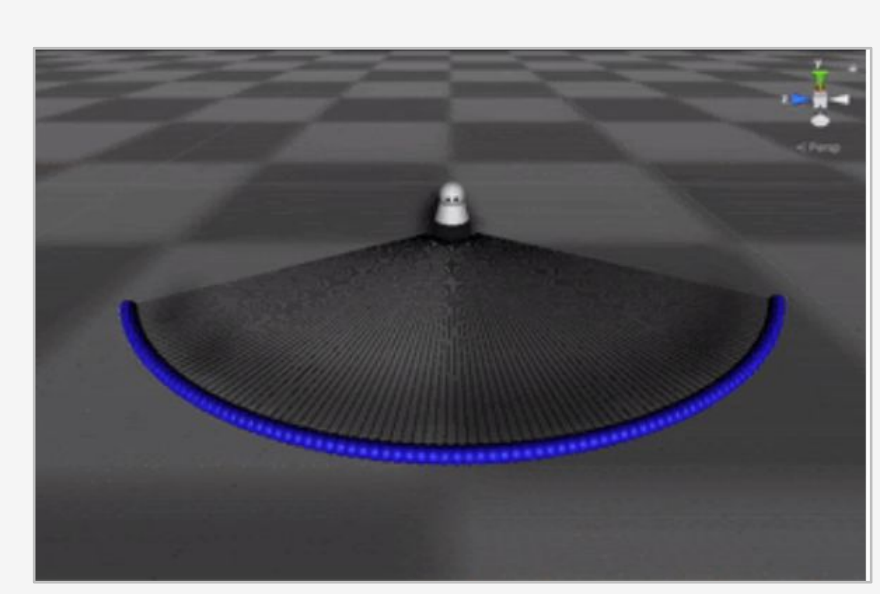


MoveToCode block-based programming in mixed reality; external view of participant [left] and view through mixed reality headset [right]

Current Work

- Creating a one-to-one virtual Kuri robot in the Unity game engine for deployment to multiple mixed reality headsets.
- Designing different sensor visualizations for non-expert users such as laser scan visualizations for Kuri within Unity to improve transparency for non-expert users.
- Experimental visualizations are being further designed for an online study informed by the interview insights.


Physical Kuri [left] and virtual Kuri [right]


Virtual Kuri Lidar visualization, initial design within Unity game engine

Outreach

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[8] Kartik Mahajan*, Thomas R. Groechel*, Roxanna Pakkar, Julia Cordero, Haemin Lee, Maja J. Matarić "Adapting Usability Metrics for a Socially Assistive, Kinesthetic, Mixed Reality Robot Tutoring Environment", In *Proceedings of 2020 International Conference on Social Robotics (ICSR '20),* Colorado, USA, Nov 2020.