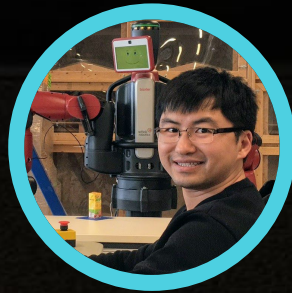


# Towards an Understanding of **Physical vs Virtual** **Robot Appendage Design**



**Zhao Han**\*



Albert Phan\*



Amia Castro\*



Fernando Sandoval Garza\*



Tom Williams



# Motivation

## Proven non-verbal interaction patterns in HRI

- **Arm** movements, gestures, **eye** gaze...
  - Require physical components, arm, head...
- **Physically-limited robots** cannot benefit →



## AR/MR allows virtual appendage but...

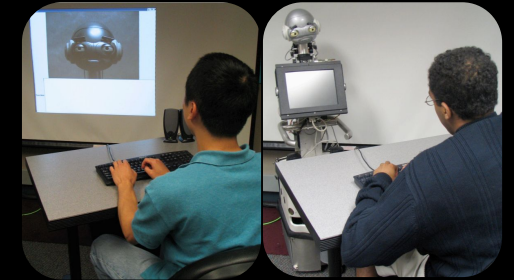
- Are virtual appendage better than physical components?



# Virtual Agents & Robots

## Virtual agents on screen ✗

- HRI literature: embodied physical presence is premier!
- Both subjectively and objectively



## AR virtual agents or virtual humans ✓

- Not bad! Perceived as physically distant & higher social presence...



# Contradictions of Screen/AR Agents

What about AR robot appendage?

Robot Design Question

Should I add an AR or real arm to my physically limited robot?

If AR Arms Are Better...

No need for real robot arms, which are **costly** & **unsafe** for nonverbal communication!

(& hard to mount one!)



# Mixture of Virtual & Physical Objects

**New knowledge** on virtuality of robot arm

A potential confound: reality match

Physical robot	AR arm	<u>Physical</u> referents
	<u>Physical</u> arm	

**Unclear:** the play of the virtuality factor of **task objects**

examines reality match/mismatch

Physical robot	AR arm	AR referents
	Physical arm	



# Experiment

**Task:** A mobile robot points at a sphere  
(x10, random target)

**Design:** 2 × 2  
between-subjects

## Referent Virtuality

*Physical:*

*Virtual:*

Artist's rendering

*Physical:*



## Arm Virtuality

*Virtual:*



# Experiment Apparatus

**Hardware:** TurtleBot2,  
WidowX arm (CAD models  
for virtual), HoloLens 2

**Referents** (may change):

- placed on an arc (within FoV)
- 45° between each other
- 3∅ from robot
- 1m from participants to middle ball

Artist's  
rendering

Physical:

Arm  
Virtuality

Virtual:

## Referent Virtuality

Physical:



Virtual:



# Hypothesis & Measures

**H1:** Equal accuracy **Accuracy:** air-tap targets

**H2:** Reality alignment mediates *efficiency* **Reaction time:** eye-tracking API of HoloLens 2, invisible objects at referents' locations

- Reality match – P (physical) → P & AR → AR: equivalent efficiency
- Reality mismatch – P → AR & AR → P: increases time to identify target

**H3:** Reality mediates *perception*

**Social presence, anthropomorphism, likability, warmth and competence**

- Reality mismatch: reduce perceived naturalness and likability





# Towards an Understanding of Physical vs Virtual Robot Appendage Design



**Zhao Han**

zhaohan@mines.edu

[zhaohanphd.com](http://zhaohanphd.com)

[@hanzhao](https://twitter.com/hanzhao)



## MIRRORLab

Mines Interactive Robotics Research

[mirrorlab.mines.edu](http://mirrorlab.mines.edu)

[@mirrorlab](https://twitter.com/mirrorlab)

This work was  
funded in part by:



## Takeaways

1. **Physically limited robots cannot** use non-verbal methods.
2. **Can we use AR virtual robot appendage?** It **may not be better** than the physical ones.
3. We plan to **compare AR & physical arm in AR & physical environment.** [bit.ly/vamhri22](http://bit.ly/vamhri22)

Any feedback/question  
is welcome!

