Mobile Cobots as Assistive Technology

Google Slides with videos can be found at
https://sites.gatech.edu/hrl/releases/

Charlie Kemp

Associate Professor, Department of Biomedical Engineering
Adjunct, School of Interactive Computing
Adjunct, School of Electrical and Computer Engineering
Georgia Tech

Co-founder & CTO, Hello Robot Inc.

hello robot™

Georgia Tech
Wallace H. Coulter Department of Biomedical Engineering
at Georgia Tech and Emory University
EMORY UNIVERSITY

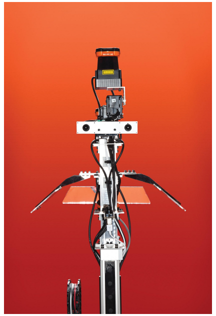
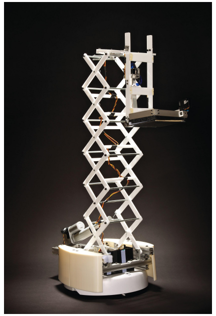
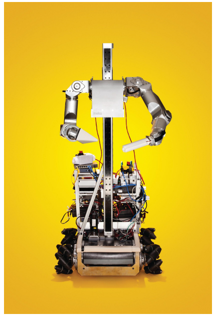
Conflict of Interest Statement

In addition to being an associate professor at Georgia Tech, Dr. Kemp (https://charliekemp.com) is a co-founder and the chief technology officer (CTO) of Hello Robot Inc. where he works part time.

Dr. Kemp owns equity in Hello Robot and is an inventor of Georgia Tech intellectual property (IP) licensed by Hello Robot. Consequently, he benefits from increases in the value of Hello Robot, and receives royalties via Georgia Tech for sales made by Hello Robot.

Mobile Cobots
(Mobile Manipulators)

- Can benefit people with disabilities
- Can help with a wide variety of tasks
- Could be useful in the near term


Photos by
Josh Meister

The Need

- Long-term disabilities
  - In the US, 12,000,000 people with disabilities need assistance with daily activities [1]
- Short-term disabilities
  - In the US by 2030 [2]
    - 635,000 total hip replacement surgeries per year
    - 1.28 million total knee replacement surgeries per year
  - “The median time to recovery of independence in walking was 12 days and to ability to perform household chores was 49 days” [3]
- Aging societies [4]

[1] Brault, Matthew W. "Americans with disabilities: 2010." Current population reports 7 (2012): 0-131.
[2] Sloan, Matthew, Ajay Premkumar, and Neil P. Sheth. "Projected volume of primary total joint arthroplasty in the US, 2014 to 2030." JBJS 100.17 (2018): 1455-1460.
[3] Hamel, Mary Beth, et al. "Joint replacement surgery in elderly patients with severe osteoarthritis of the hip or knee: decision making, postoperative recovery, and clinical outcomes." Archives of internal medicine 168.13 (2008): 1430-1440.
[4] Ortman, Jennifer M., Victoria A. Velkoff, and Howard Hogan. “An aging nation: the older population in the United States”. Washington, DC: United States Census Bureau, Economics and Statistics Administration, US Department of Commerce, 2014.

Types of Tasks

- **Activities of Daily Living (ADLs)**
  - Feeding, toileting, transferring, dressing, and hygiene
  - Predictive of ability to live independently

- **Instrumental Activities of Daily Living (IADLs)**
  - Housework, food preparation, taking medications, …

[images] found on the internet and used without permission

Types of Tasks

- **Activities of Daily Living (ADLs)**
  - Feeding, toileting, transferring, dressing, and hygiene
  - Predictive of ability to live independently
  - Manipulation near the person's body

- **Instrumental Activities of Daily Living (IADLs)**
  - Housework, food preparation, taking medications, …
  - Manipulation of objects in the environment

Robotic Opportunities

- Provide **independence**
- Robots preferred for some tasks [1]
- 24/7 personalized assistance

[1] *Domestic robots for older adults: Attitudes, preferences, and potential*, Cory-Ann Smarr, Tracy L. Mitzner, Jenay M. Beer, Akanksha Prakash, Tiffany L. Chen, Charles C. Kemp, and Wendy A. Rogers. International Journal of Social Robotics, 6(2):229–247, 2014.
[image] from Willow Garage

Commercial Assistive Robots

- Robotic Prostheses
- Robotic Orthoses / Exoskeletons
- Wheelchair Mounted Robot Arms
- Desktop Robots

DynamicArm by Ottobock

My Spoon by SECOM

JACO by Kinova

Myomo by Myomo Inc.

Benefits of Mobile Cobots

- Operate independently from the user
- No don/doff
- Assist diverse users
- Potential for mass market product

[image] from Willow Garage

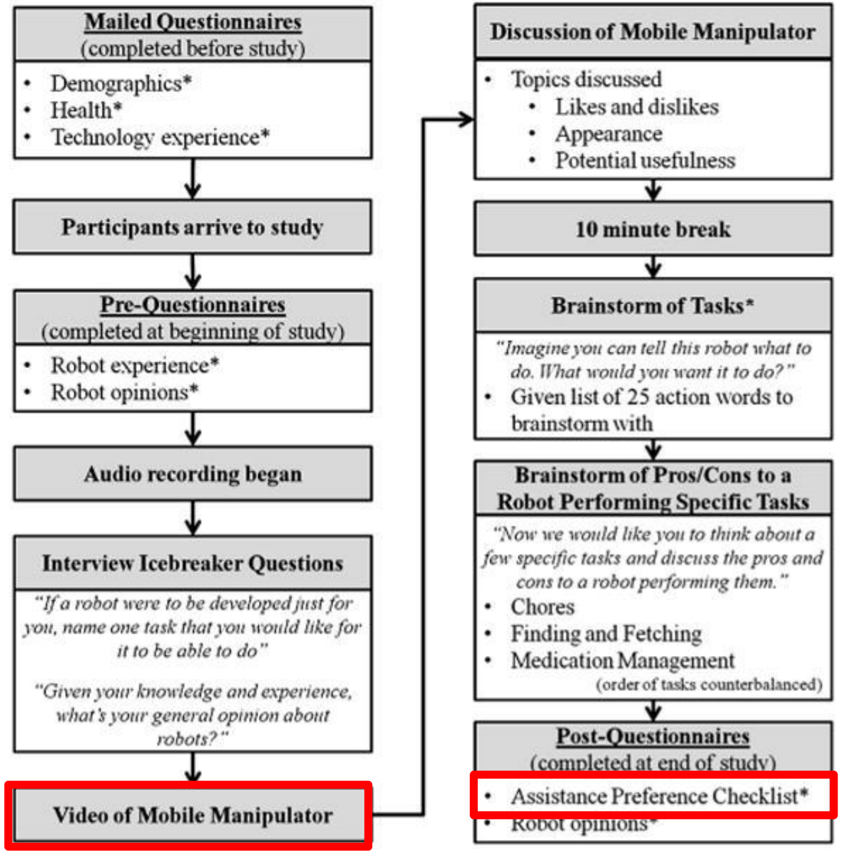
Are people open to using mobile cobots?

Open to Assistance from Mobile Cobots

- Since 2007, hundreds of participants
  - Older adults
  - Nurses
  - People with severe motor impairments

Older Adults are Open to Assistance

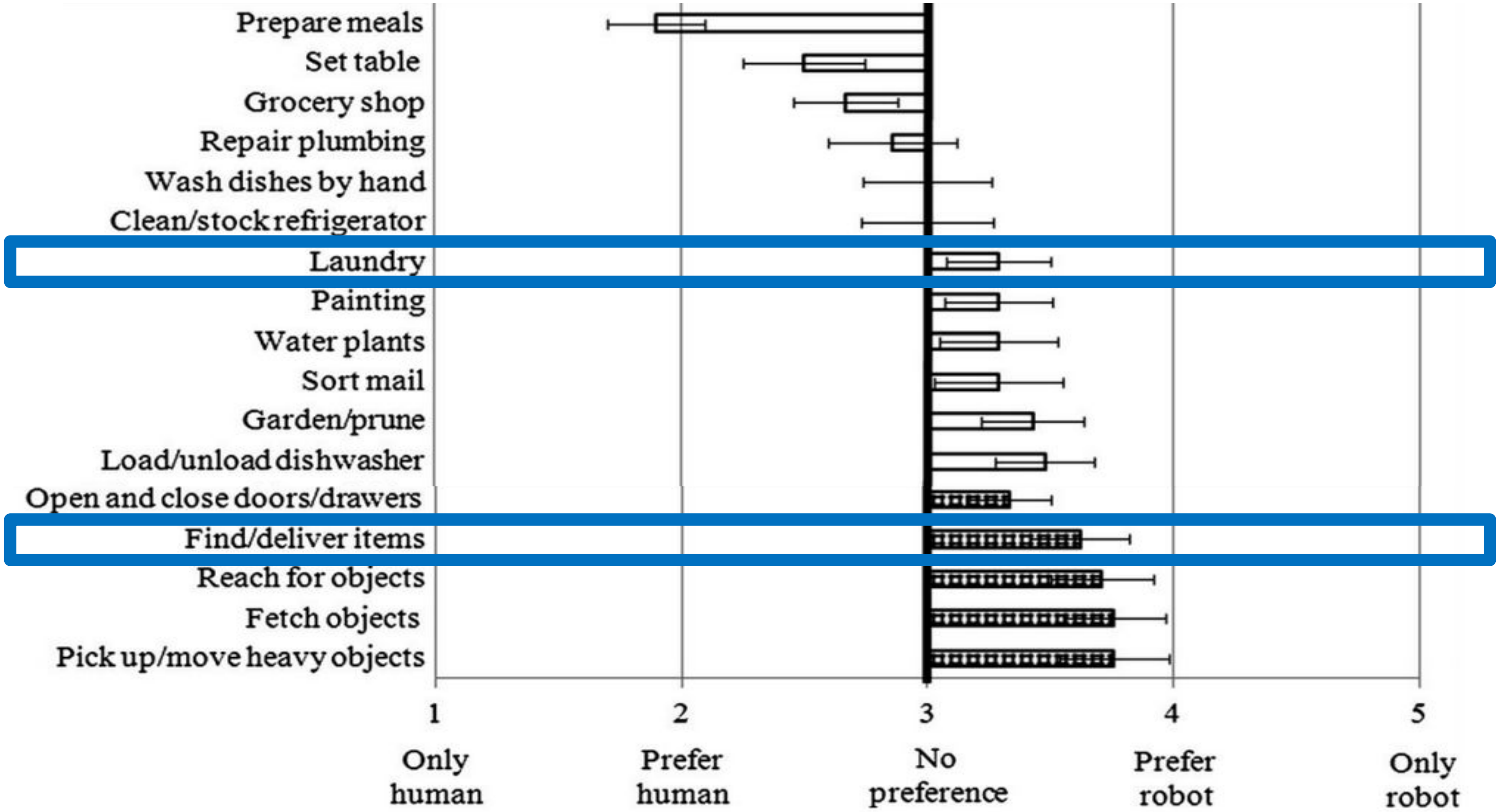
Structured Group Interview and Questionnaires with Older Adults (N=21)



Domestic robots for older adults: Attitudes, preferences, and potential, Cory-Ann Smarr, Tracy L. Mitzner, Jenay M. Beer, Akanksha Prakash, Tiffany L. Chen, Charles C. Kemp, and Wendy A. Rogers. International Journal of Social Robotics, 6(2):229–247, 2014.

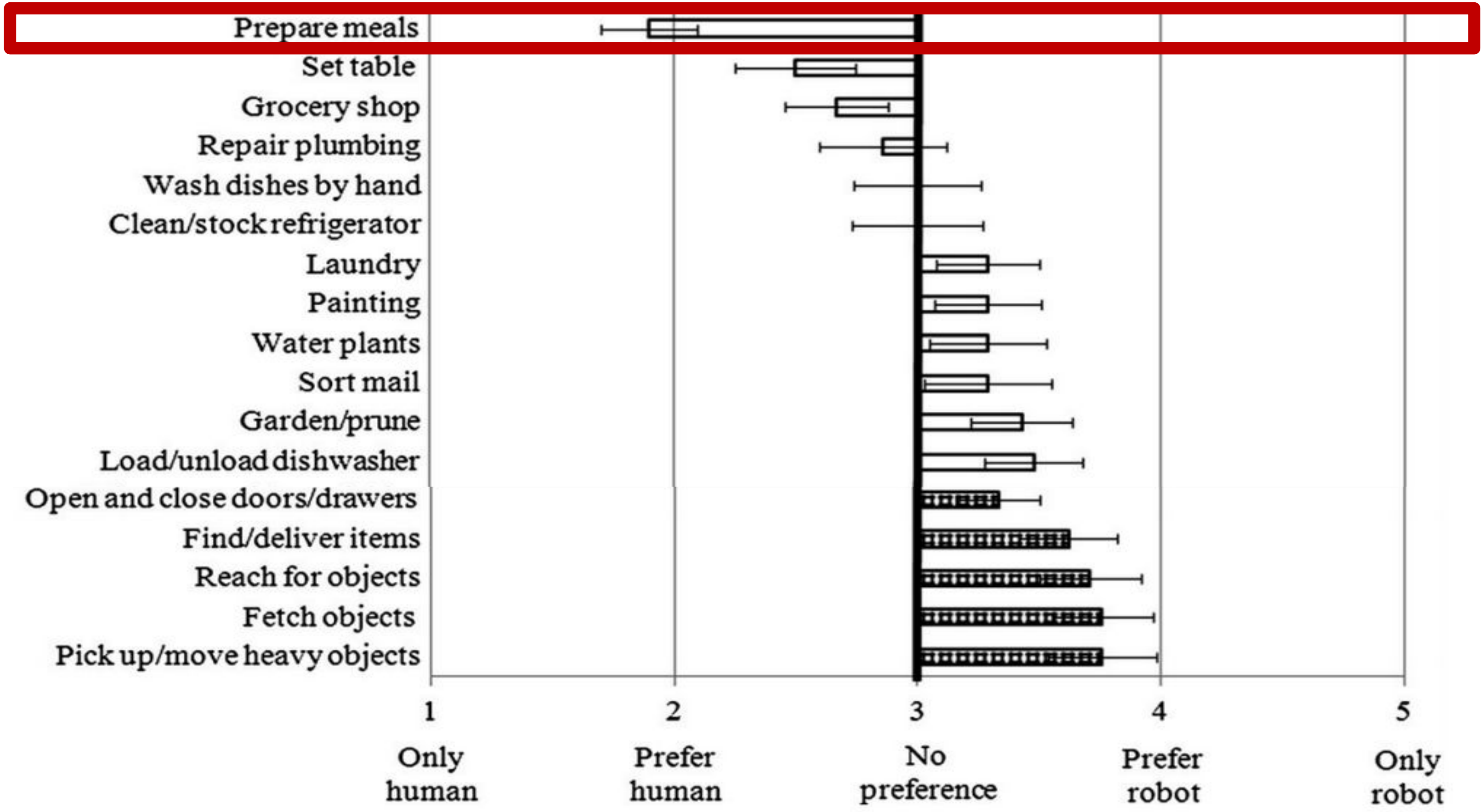
Preferred Robots for Some Tasks

(N=21, results after PR2 video and structured group interview)



Preferred Humans for Others

(N=21, results after PR2 video and structured group interview)



Autonomous Delivery of Medicine to Older Adults at the Aware Home via RFID (N=12)

Older Adults Medication Management in the Home: How can Robots Help? Akanksha Prakash, Jenay M. Beer,Travis Deyle, Cory-Ann Smarr, Tiffany L. Chen, Tracy L. Mitzner, Charles C. Kemp, and Wendy A. Rogers, 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI), 2013

More Open to Robotic Assistance After Using the PR2

(N=12, POST is after PR2 autonomously delivered medicine to them)

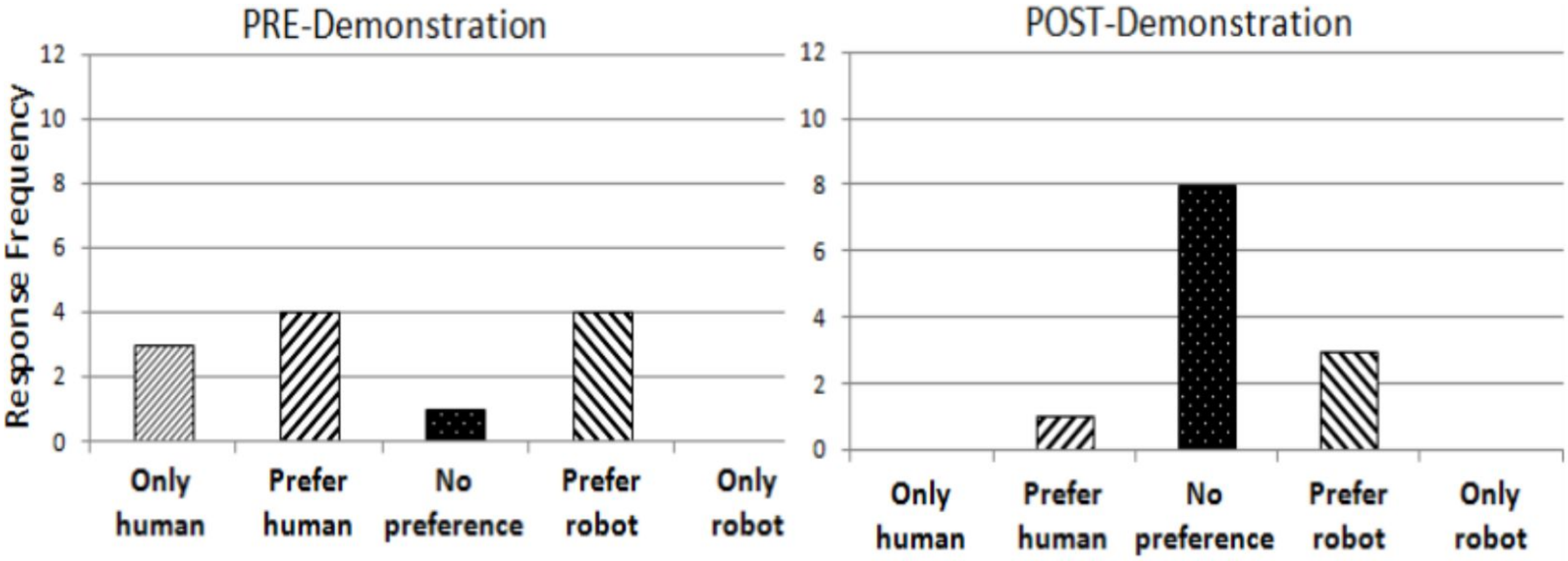


Fig. 4. Human versus robot assistance with delivering medication.

But Not for Everything

(N=12, POST is after PR2 autonomously delivered medicine to them)

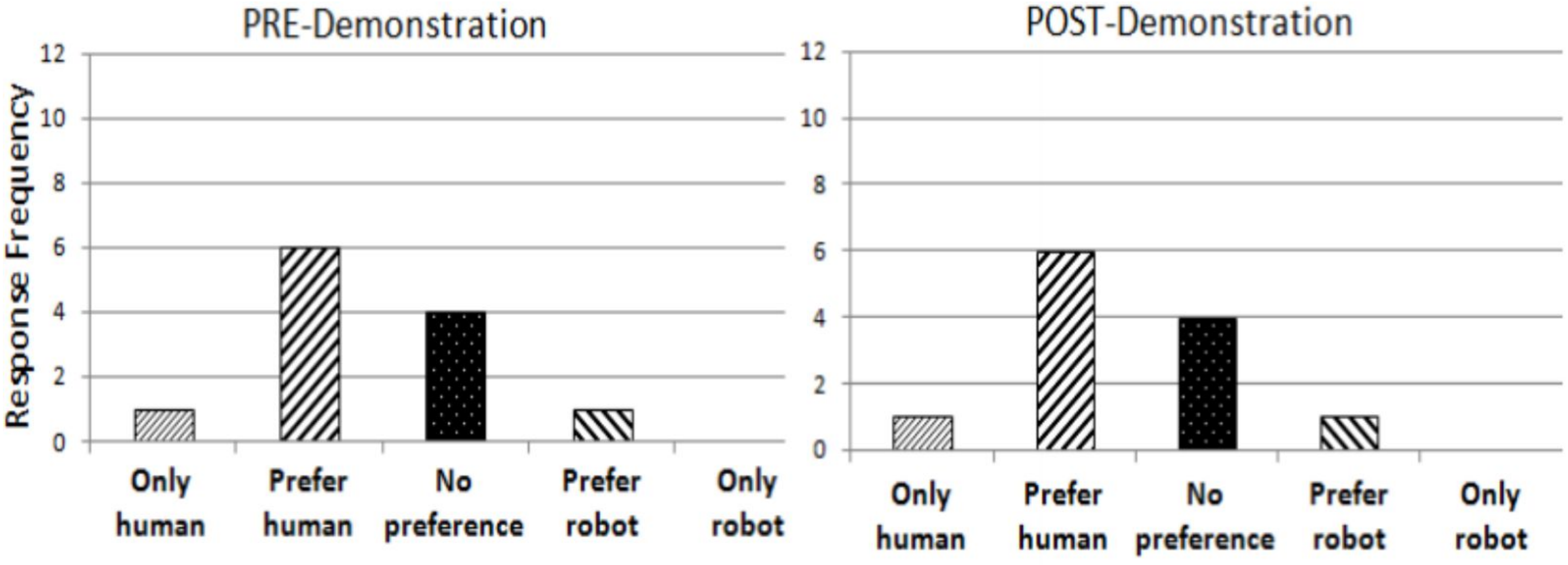


Fig. 5. Human versus robot assistance with taking medication.

Older Adults Open to Partner Dancing with Robots for Health (N=16)

Construct	Post Median	p
Usefulness	6	.012*
Ease of Use	6	<.001***
Enjoyment	5.8	.009**

Wilcoxon signed-rank tests with a test score of 4 = "Neutral."

7-point scale where 1 = "Strongly Disagree," 4 = "Neutral," 7 = "Strongly Agree."

Question	Pre Median	Post Median	p
Ease of Use	4.3	6	.0012**

Wilcoxon signed-rank test

Older Adults' Acceptance of a Robot for Partner Dance-based Exercise, Tiffany L. Chen, Jenay M. Beer, Tapomayukh Bhattacharjee, Lena H. Ting, Madeleine E. Hackney, Wendy A. Rogers, Charles C. Kemp, PloS ONE, 2017.

How can mobile cobots help?

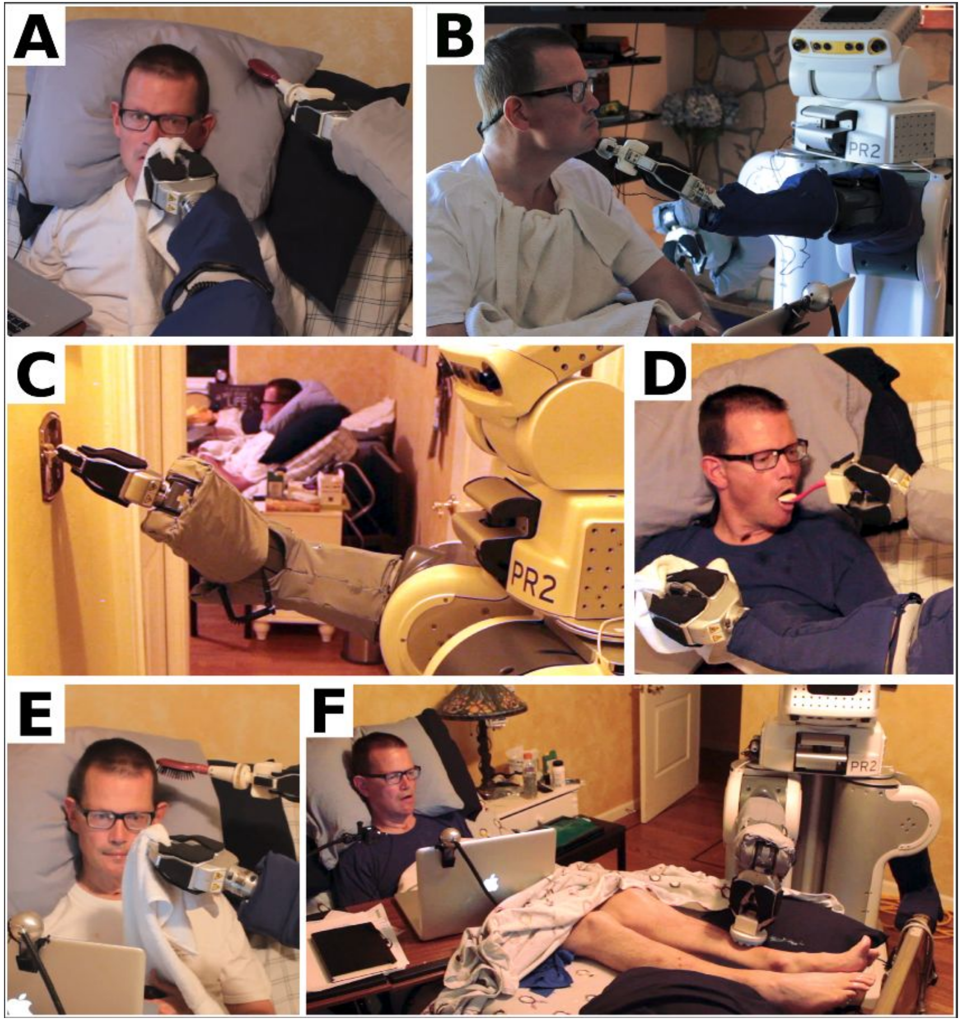
Image from https://www.mercurynews.com/2013/10/11/qa-with-henry-evans-mute-quadriplegic-and-robotics-pioneer/

the no
` 1 2 3 4 5 6 7 8 9 0 - =
Tab q w e r t y u i o p [ ] \
CAPS a s d f g h j k l ; ' Return
< z x c v b n m , . /
Ctrl Win Alt Alt Gr Win Menu Ctrl
Panasonic

Teleoperation via Augmented Reality

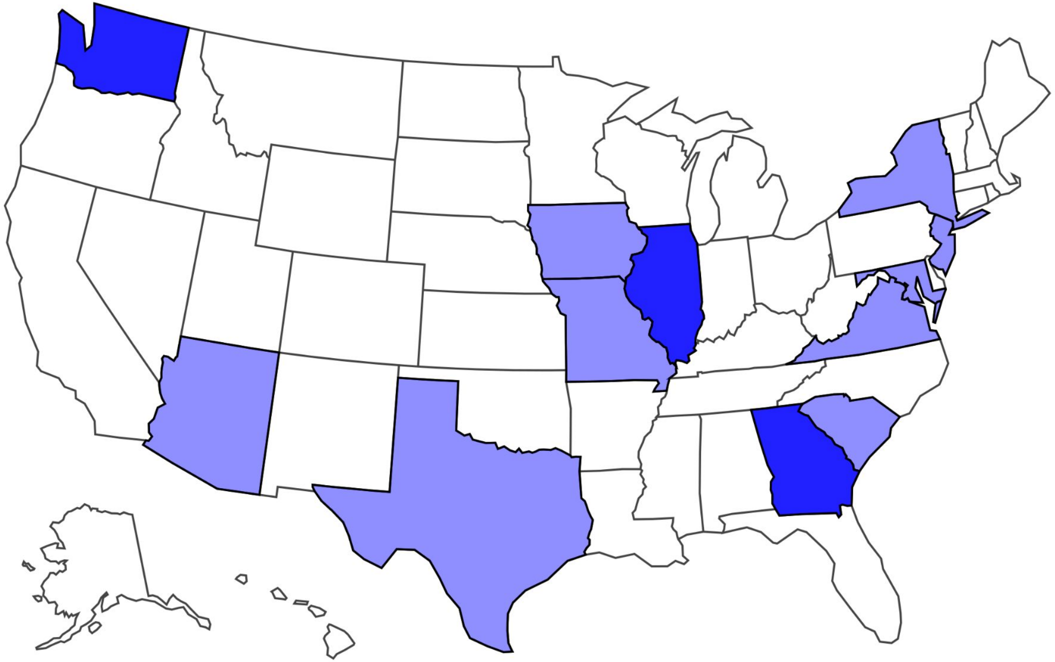
In-home and remote use of robotic body surrogates by people with profound motor deficits, Phillip M. Grice and Charles C. Kemp, PLoS ONE 14(3), 2019.

Control Interface
monty1wan.bme.gatech.edu:8008/assistive_teleop/vci.html
Phillip
Main Menu
Look
Spine
Left Hand
Right Hand
Drive
Controls
Step Size
XS
S
M
L
Position/Rotation
Hand Position
Wrist Rotation
3D Peek
Move Aside
Move to Setup
Re-zero Skin
Gripper
4x

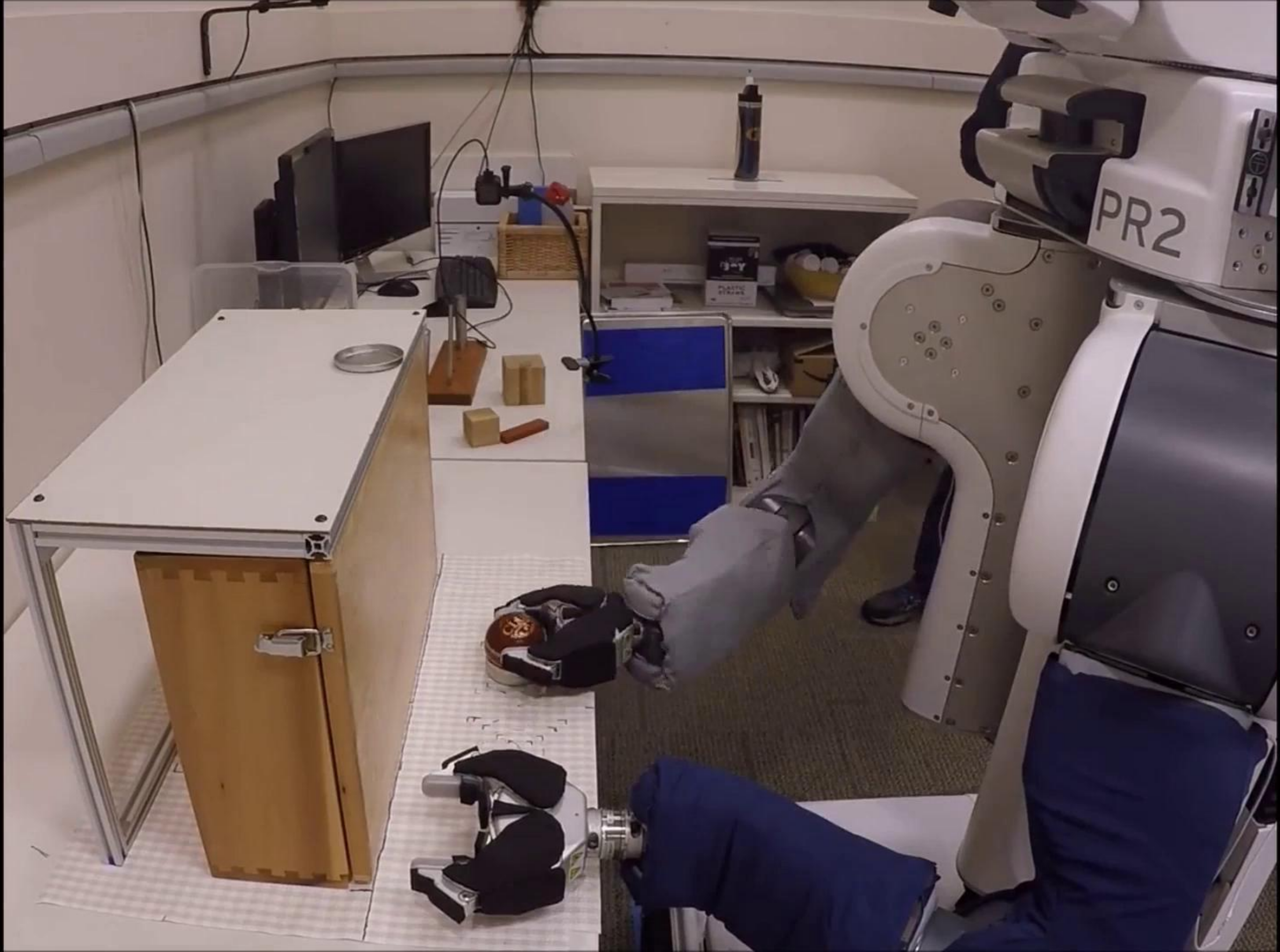

A
B
PR2
C
PR2
D
E
F
PR2


Realtime

15 Participants – Geographic Location



40x



Causes of Motor Impairment

6 Spinal Muscular Atrophy (SMA)

3 Muscular Dystrophy (Duchenne/Becker)

3 Spinal Cord Injury

1 Amyotrophic Lateral Sclerosis (ALS)

1 Arthrogryposis

1 Dejerine-Sottas

ARAT Threshold: 9/57 with best arm

Computer Access Devices

4 – Trackball

3 – Touchpad

3 – Head-mouse (TrackerPro, 2x HeadMouse Extreme)

2 – Standard mouse

1 – Eye-gaze (Tobii)

1 – Touchpad w/Stylus held in mouth

1 – Speech (Dragon MouseGrid)

Improvement Exceeded Conservative Minimal Clinically Important Difference (MCID)

Lang, et al. 2008

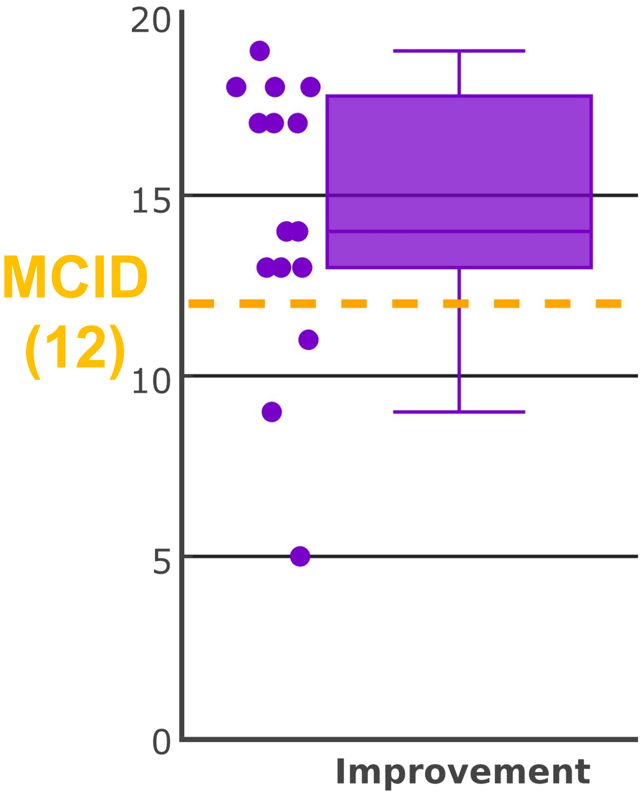
- MCID: 12
  for dominant arm

Van der Lee, et al. 2001

- MCID: 5.7
  10% of scale

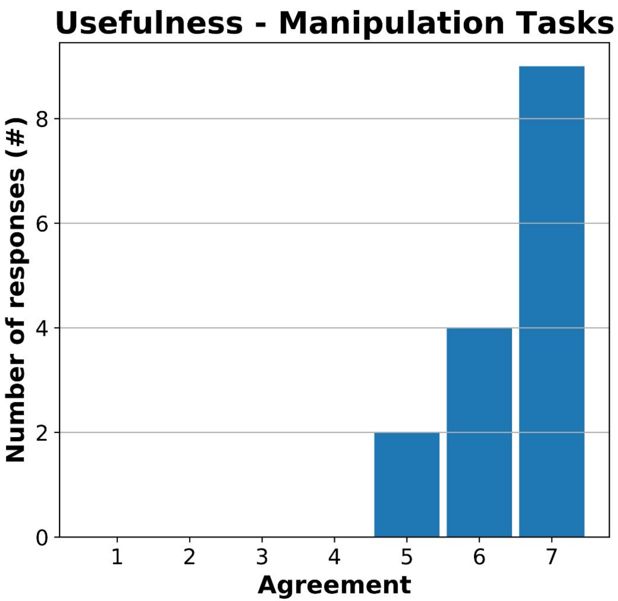
C. E. Lang, D. F. Edwards, R. L. Birkenmeier, and A. W. Dromerick, “Estimating minimal clinically important differences of upper-extremity measures early after stroke,” Archives of physical medicine and rehabilitation, vol. 89, no. 9, pp. 1693– 1700, 2008.

J. H. Van der Lee, V. De Groot, H. Beckerman, R. C. Wagenaar, G. J. Lankhorst, and L. M. Bouter, “The intra-and interrater reliability of the action research arm test: A practical test of upper extremity function in patients with stroke,” Archives of physical medicine and rehabilitation, vol. 82, no. 1, pp. 14–19, 2001.



1-tailed Wilcoxon signed-rank test vs MCID: W=96, **p=.021**

Perceived Usefulness

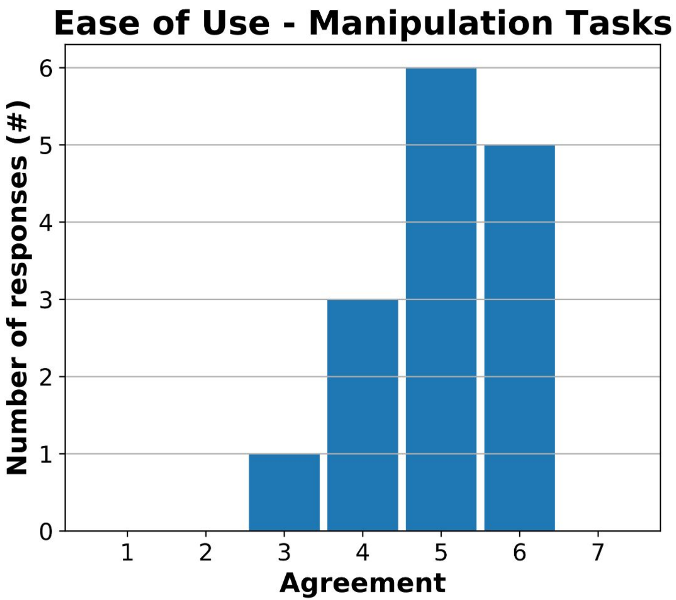


Wilcoxon signed-rank test vs neutral:
W=120, p=.000258

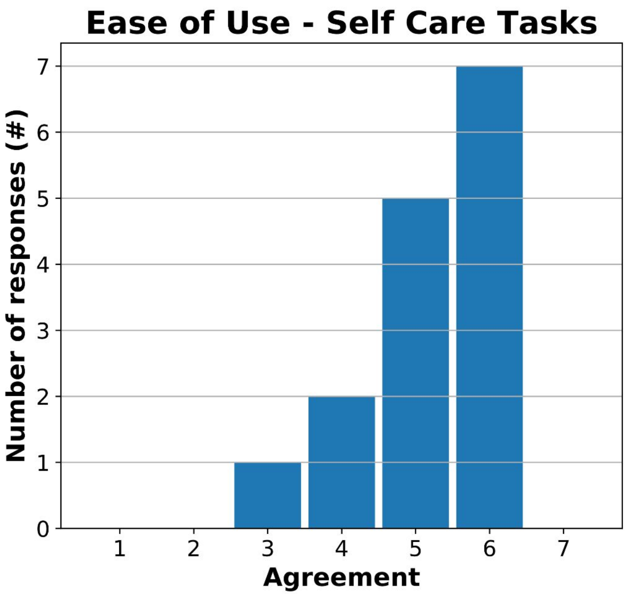
Wilcoxon signed-rank test vs neutral:
W=105, p=.000402

1: Strongly Disagree
2: Disagree
3: Somewhat Disagree
4: Neither Agree nor Disagree
5: Somewhat Agree
6: Agree
7: Strongly Agree

Perceived Ease of Use



Wilcoxon signed-rank test vs neutral:
W=74, p=.00264



Wilcoxon signed-rank test vs neutral:
W=87.5, p=.00142

1: Strongly Disagree
2: Disagree
3: Somewhat Disagree
4: Neither Agree nor Disagree
5: Somewhat Agree
6: Agree
7: Strongly Agree

Main Limitations

- Slow operation
- Errors

Task-specific Applications that Incorporate Autonomy

Tasks

- Home automation
- Object retrieval
- Hygiene
- Feeding
- Bedside assistance
- Dressing

Autonomous Behaviors via Augmented Reality Programming

ROS Commander (ROSCo): Behavior Creation for Home Robots, Hai Nguyen, Matei Ciocarlie, Kaijen Hsiao, and Charles C. Kemp, IEEE International Conference on Robotics and Automation, 2013.


Real Time
PR2

Object Retrieval

EL-E: An Assistive Mobile Manipulator that Autonomously Fetches Objects from Flat Surfaces, Advait Jain and Charles C. Kemp, Autonomous Robots, 2010.

Dusty: An Assistive Mobile Manipulator that Retrieves Dropped Objects for People with Motor Impairments, Chih-Hung King, Tiffany L. Chen, Zhengqin Fan, Jonathan D. Glass, and Charles C. Kemp, Disability and Rehabilitation: Assistive Technology, 2011.


8x

Rank	Object Class	Image	Rating Mean	Rating Stdev.	Weight (grams)	Max size (cm)
1	TV Remote		6.64	0.57	90	18
2	Medicine Pill		6.36	1.55	1	2.2
3	Cordless Phone		6.28	1.31	117	15
4	Prescription Bottle		6.08	1.31	25	7
4	Fork		6.08	1.12	39	18
6	Glasses		6.00	1.53	23	14
7	Toothbrush		5.96	1.81	15	19
8	Spoon		5.92	1.19	38	17
9	Cell Phone		5.88	1.69	76	9

A list of household objects for robotic retrieval prioritized by people with ALS, Young Sang Choi, Travis Deyle, Tiffany Chen, Jonathan D. Glass, and Charles C. Kemp, *ICORR 2009.*

Real-time
Healthcare Robotics Lab, Georgia Tech


Healthcare Robotics Lab, Georgia Institute of Technology

Robot-assisted Hygiene

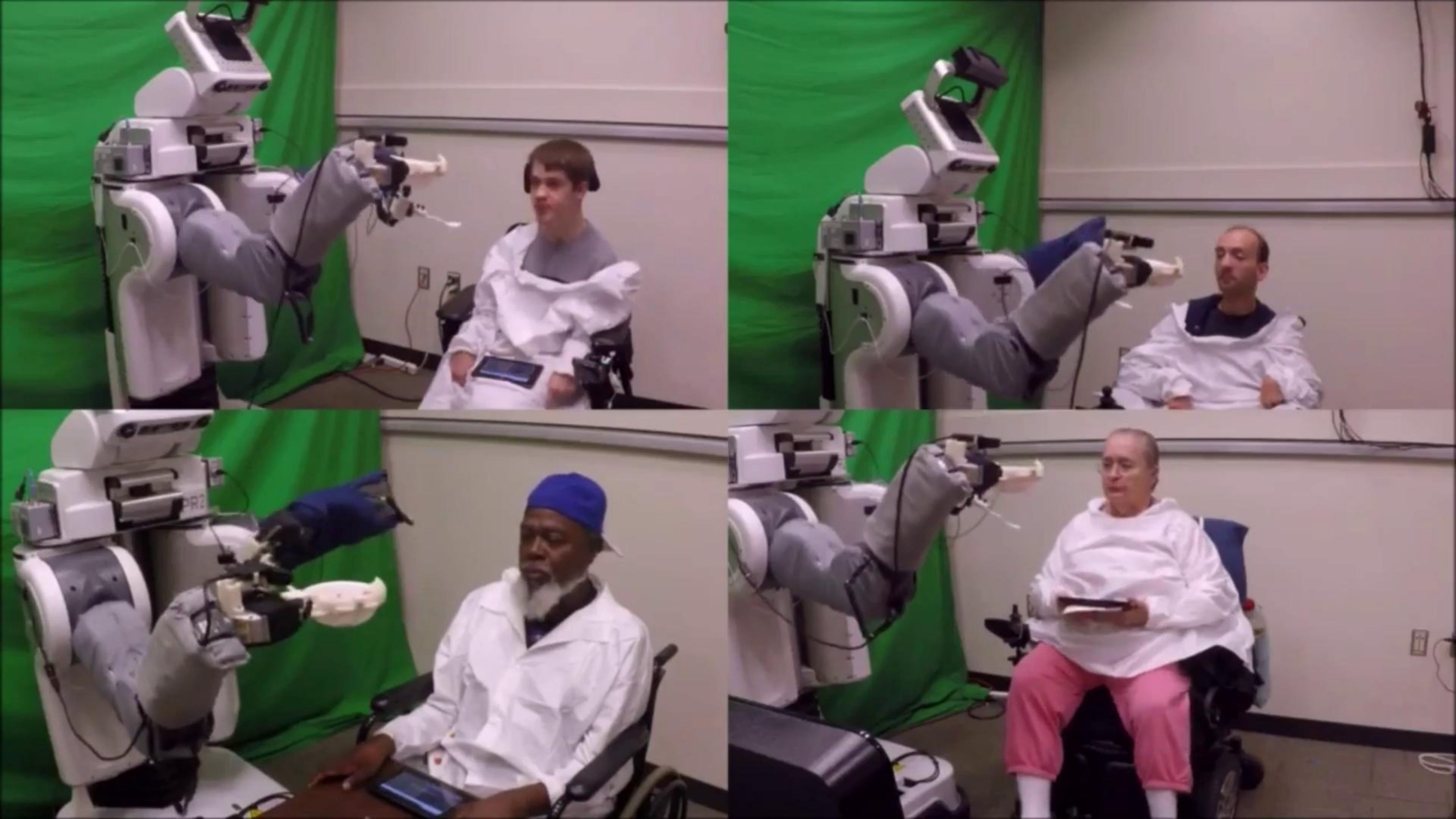
Assistive Mobile Manipulation for Self-Care Tasks Around the Head, Kelsey Hawkins, Phillip M. Grice, Tiffany L. Chen, Chih-Hung King, and Charles C. Kemp, 2014 IEEE Symposium on Computational Intelligence in Robotic Rehabilitation and Assistive Technologies, 2014.

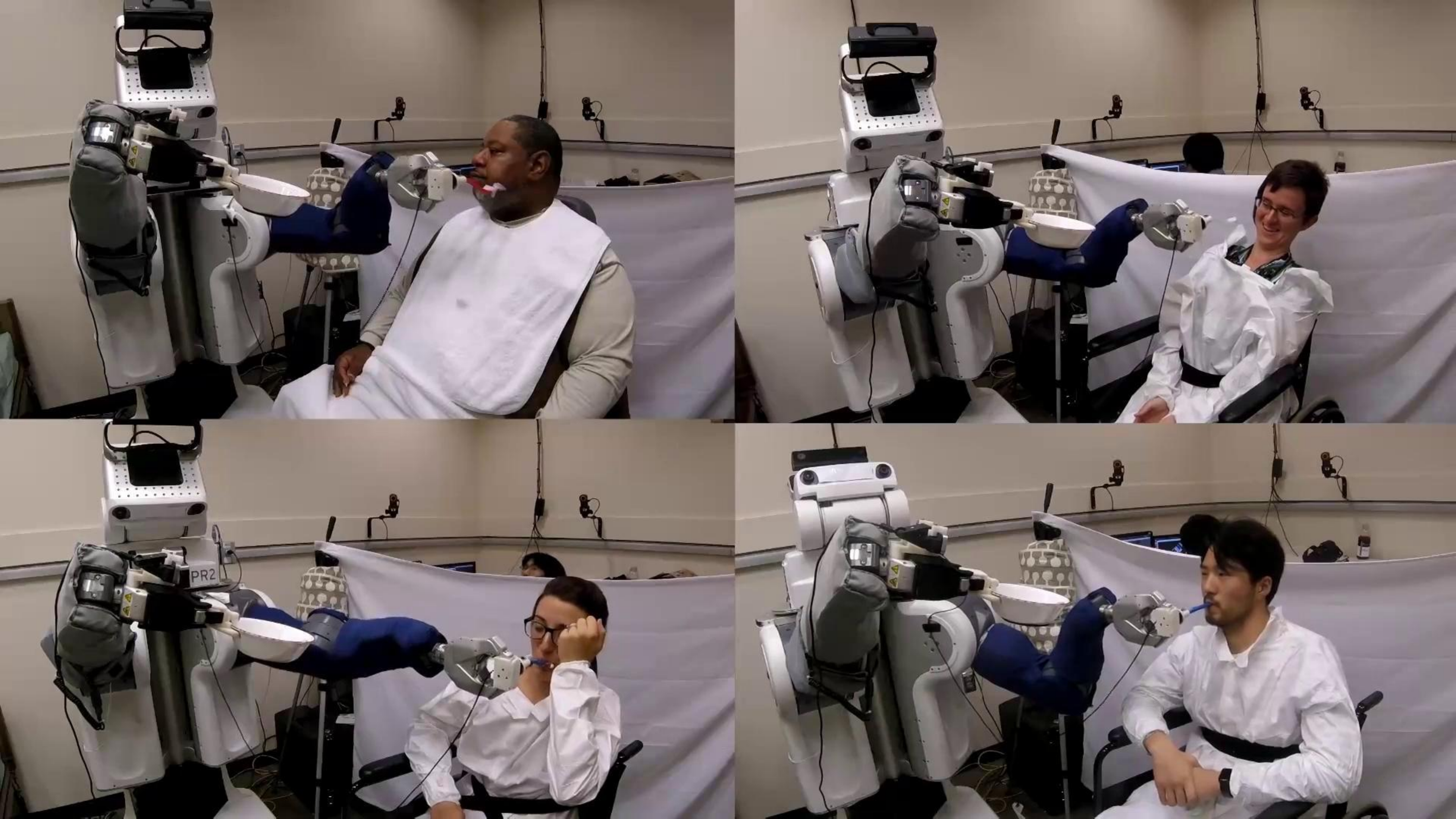

PR2
2x

Robot-assisted Feeding

Active Robot-Assisted Feeding with a General-Purpose Mobile Manipulator: Design, Evaluation, and Lessons Learned, Daehyung Park, Yuuna Hoshi, Harshal P Mahajan, Ho Keun Kim, Zackory Erickson, Wendy A Rogers, Charles C Kemp, Robotics and Autonomous Systems, 2019.


30x
The user successfully fed himself 20
times without any failure.


PR2


PR2

Bedside Assistance

A system for bedside assistance that integrates a robotic bed and a mobile manipulator, Ariel S. Kapusta, Phillip M. Grice, Henry M. Clever, Yash Chitalia, Daehyung Park, Charles C. Kemp, PLoS ONE 14(10), 2019.

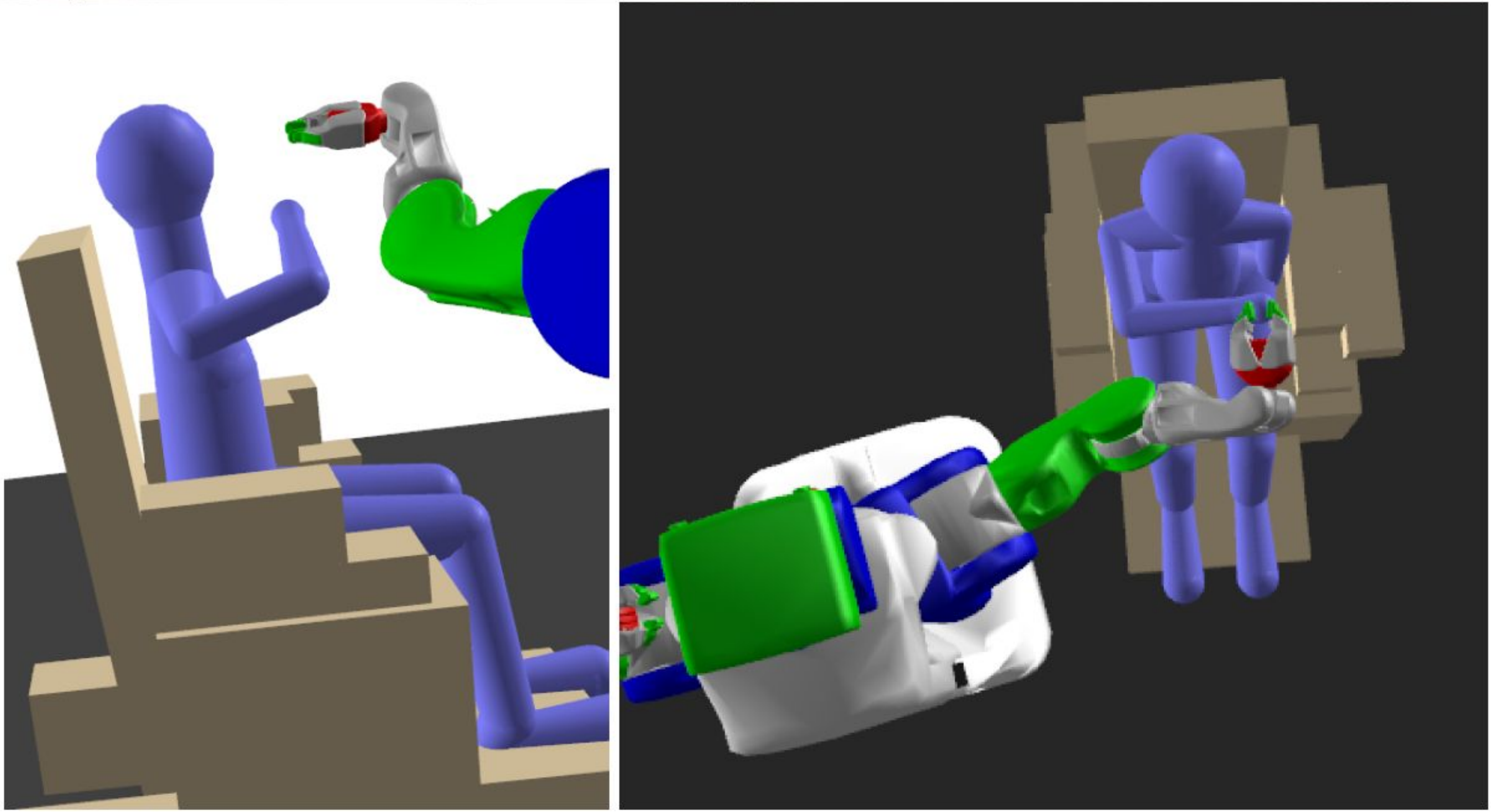

Teleoperation
4x realtime

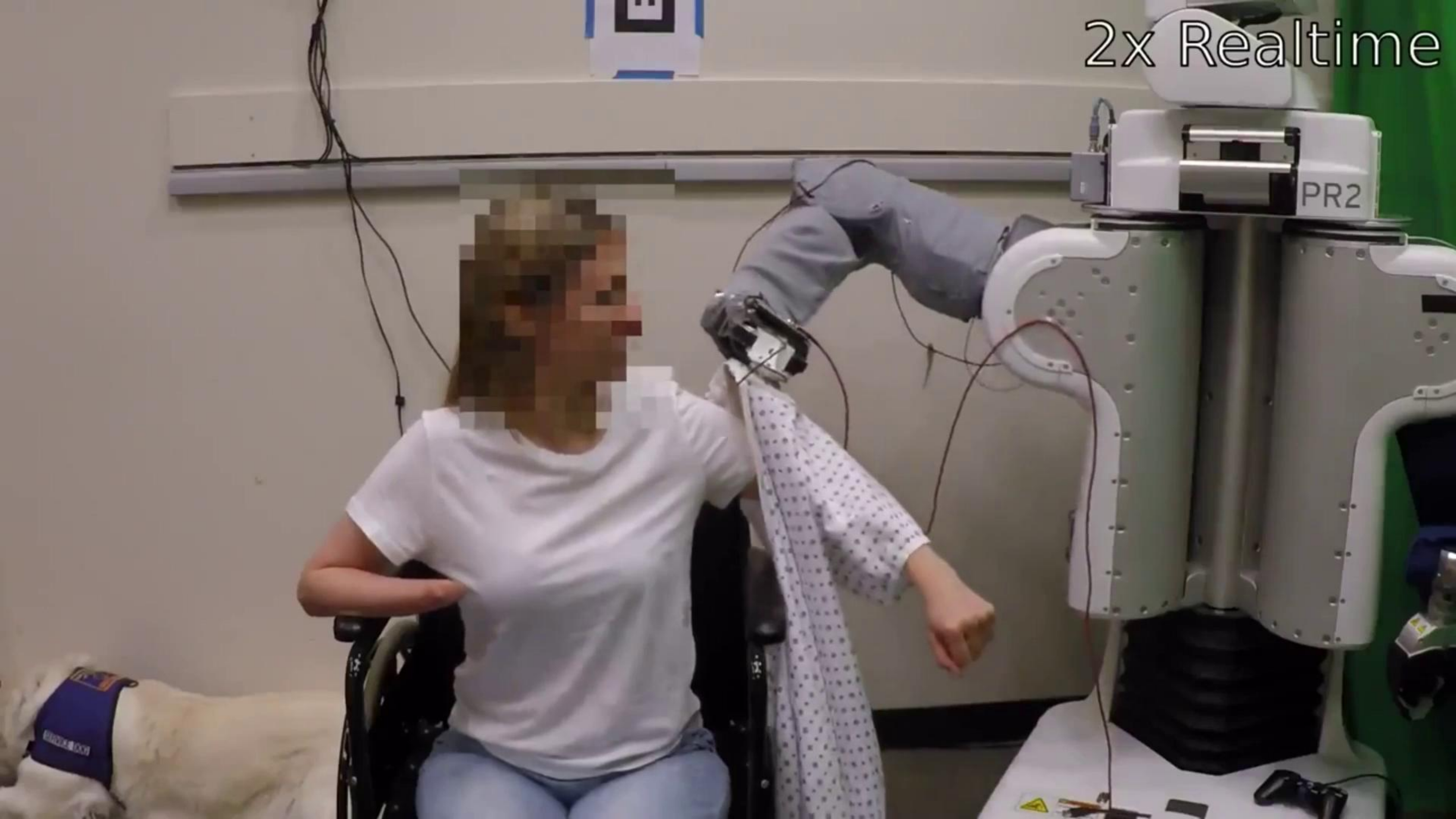

PR2
2x

Robot-assisted Dressing

Personalized collaborative plans for robot-assisted dressing via optimization and simulation, Ariel Kapusta, Zackory Erickson, Henry M. Clever, Wenhao Yu, C. Karen Liu, Greg Turk, Charles C. Kemp, Autonomous Robots, 2019.

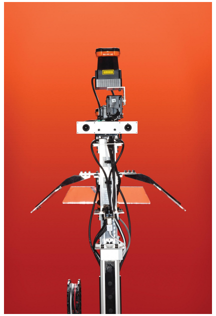
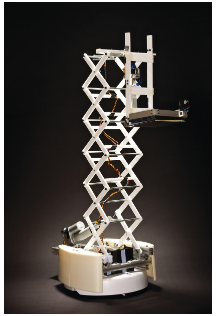
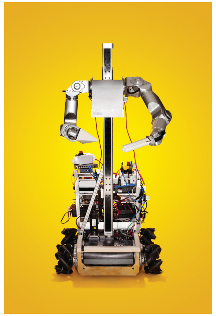
Search for a personalized solution based on **what a person is capable of doing**.




2x Realtime
PR2

Mobile Cobots

- Can benefit people with disabilities
- Can help with a wide variety of tasks
- Could be useful in the near term


Photos by
Josh Meister

What's the catch?

Why aren’t people benefitting today?

The Details Matter

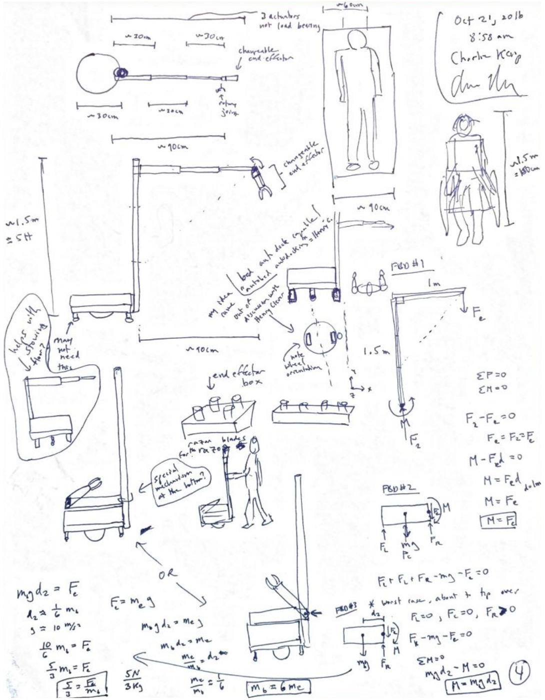
Released in 2010
$400,000
227 kg (~500 lb)
67 cm wide (~2.2 ft)

[image] from Willow Garage; specifications from https://robots.ieee.org/robots/pr2/

Frustration Leads to Invention

Minimize the actuator requirements while maximizing the capabilities.

- affordable
- compact
- lightweight
- humancentric
- capable



My Initial Georgia Tech Notes
October 2016

Georgia Tech's Prototype
March 2017

Hello Robot's Product
July 2020

2016	2017		2018	2019	2020

Georgia Tech

hello robot™

Live Demo of the Stretch RE1

The Stretch RE1 is a product sold by Hello Robot Inc. based on licensed intellectual property created in Prof. Kemp's lab at Georgia Tech. Prof. Kemp owns equity in and works part time for Hello Robot Inc.

https://hello-robot.com/