# Affordable Therapy and Service Robots for Health and Function Monitoring

[1-3] **Michelle J. Johnson, PhD**

[1] Physical Medicine and Rehabilitation, University of Pennsylvania

[2] BioEngineering, University of Pennsylvania

[3] Rehabilitation Robotics Research and Design Lab (RRRD), Pennsylvania Institute of Rehabilitation Medicine

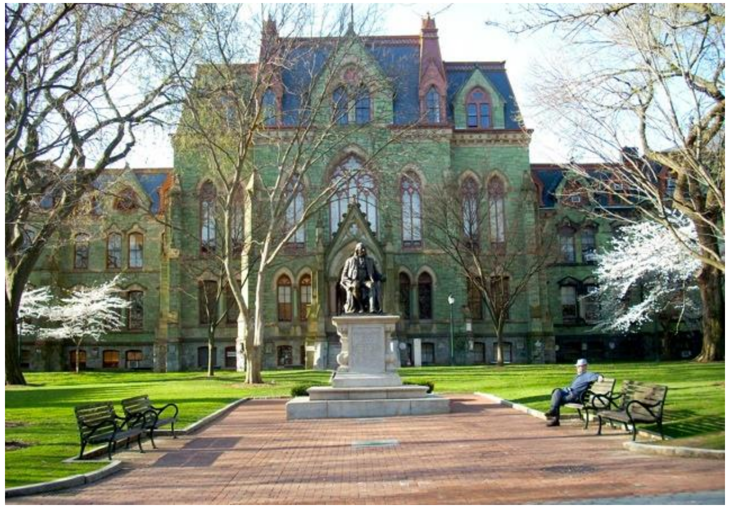
September 25, 2018
Presentation at PHM 2018 Workshop

# Financial Disclosures

1. Patents filed on Rehab CARES robot system
2. Equity in a spin-off company of UPENN called Recupero Robotics, LLC.


LOVE

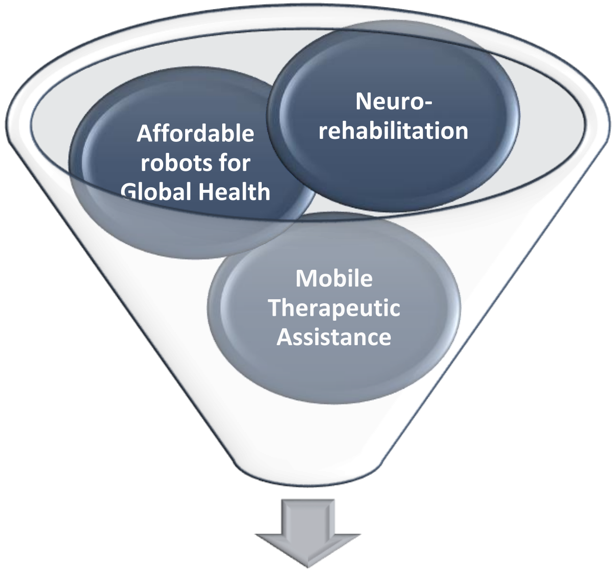

PENN MEDICINE at RITTENHOUSE
Department of Physical Medicine and Rehabilitation



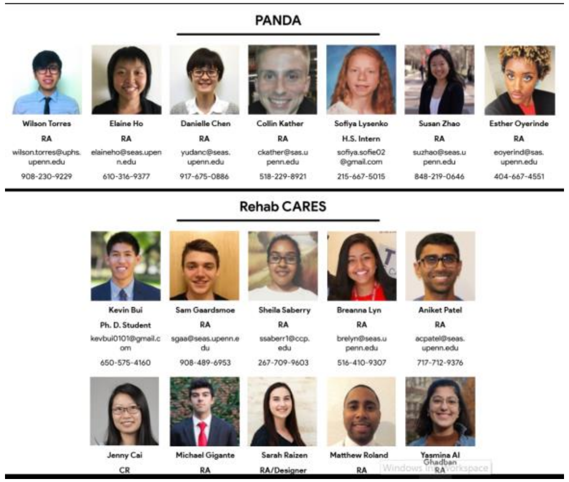
# UPENN LOVE

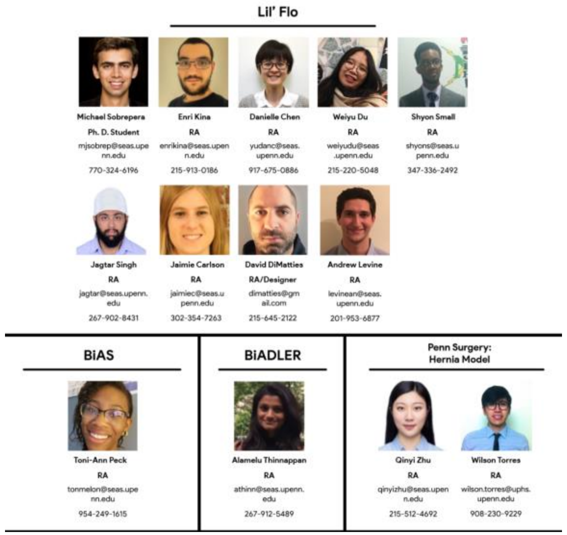
# Rehabilitation Robotics Lab

- The lab consists of an interdisciplinary team working in the fields of **robotics**, **rehabilitation**, and **neuroscience**.
- Our mission is to translate research findings into the development of affordable, assistive and therapeutic robots that can provide effective neurorehabilitation both nationally, and around the world.




**Core Research Areas**



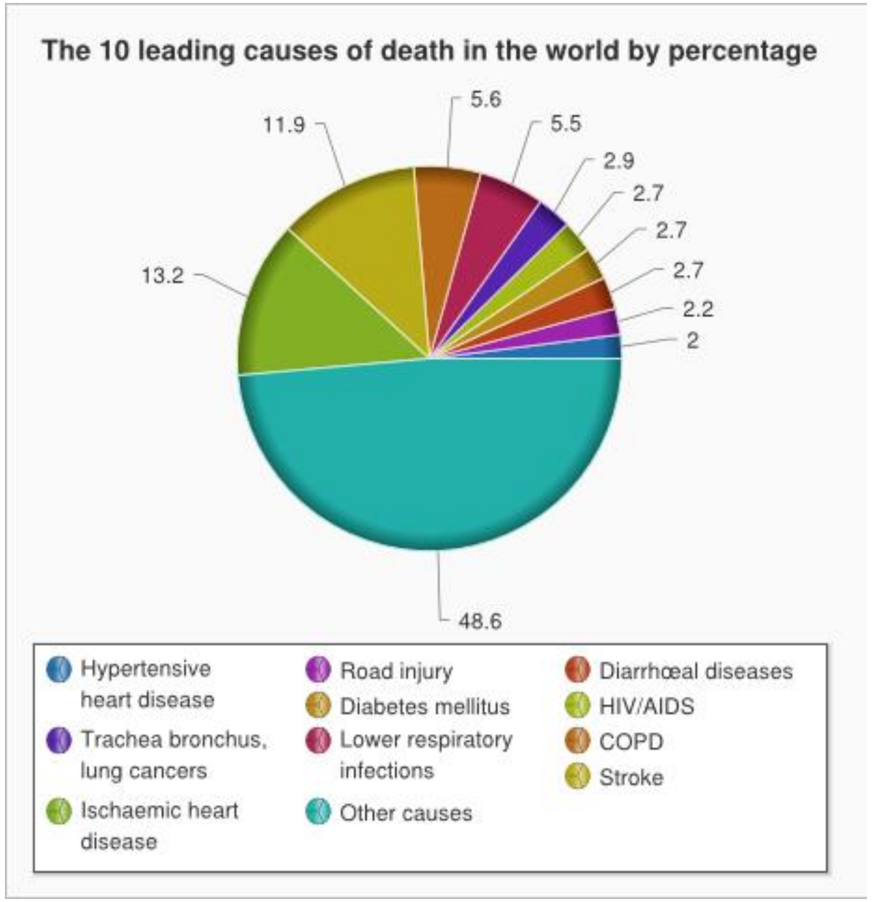

# Lab Team (Past and Present)

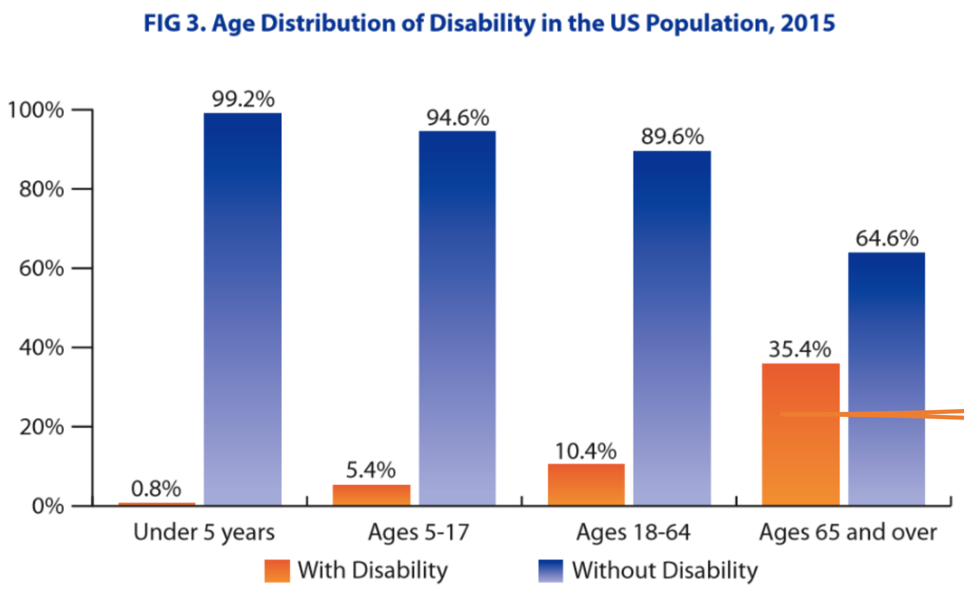
# Learning Objectives

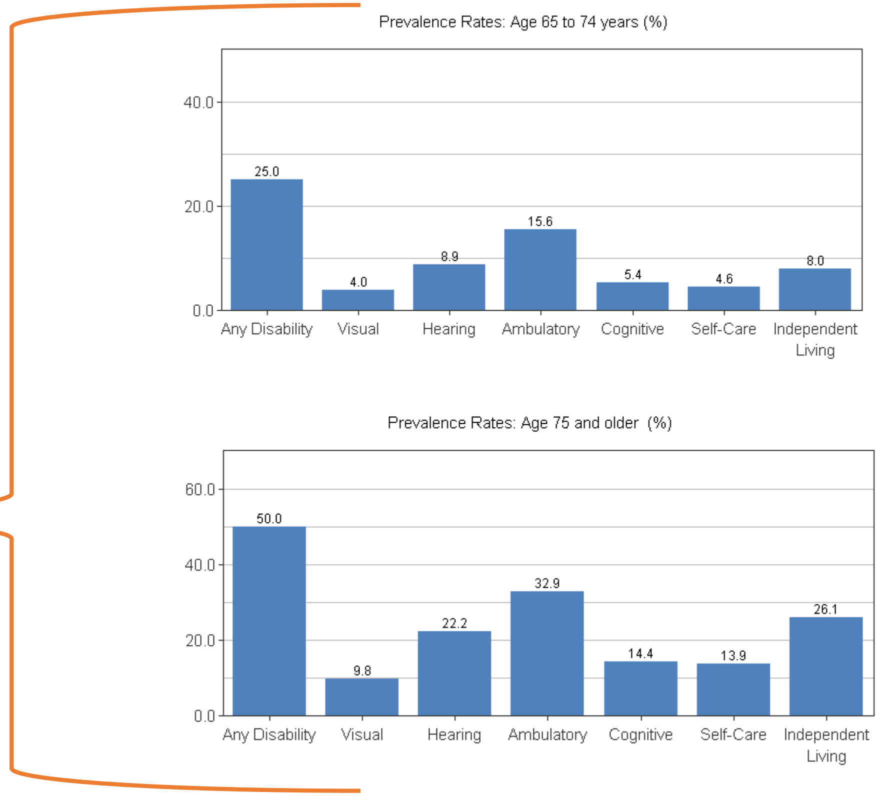
- Background
- Technology-assisted rehabilitation
- Case for Therapy and Service Robots in Community
- Integrated Systems Health Management? How work?

# Motivation

- Communicable and Non-communicable diseases.
  - NCDs were 68% of all deaths globally in 2012.
  - It is estimated to increase to 73% by 2020.
  - Cardiovascular diseases account for about 30% of NCD deaths (~17.7 million)
  - Stroke account for about 11.9% of NCDs deaths.
  - Survival often means living with disability or decreased function
- Ageing Populations
  - Populations are aging → 20-30% over 65 age by 2030;
  - Age is a leading risk factors for many diseases.





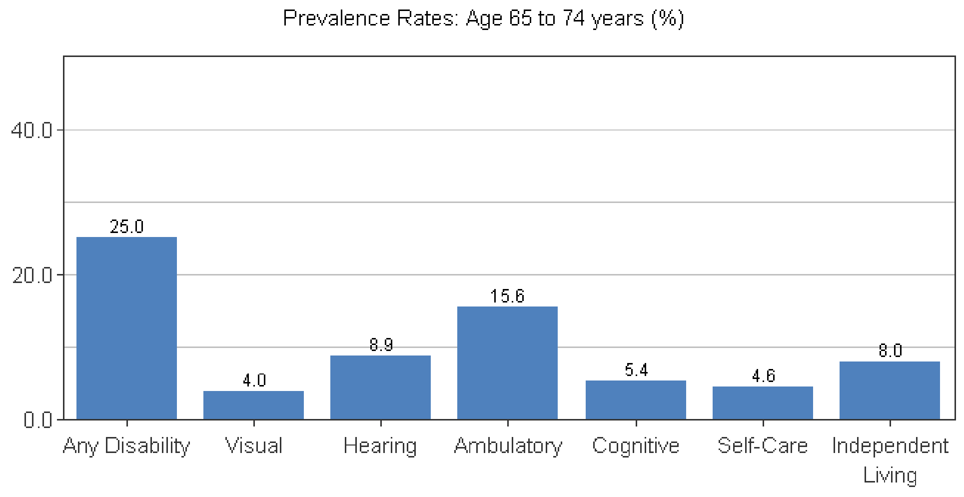




# Disability and Age: USA

Ref: 2016 Disability Statistics
by Lewis Kraus, MPH, MCP at the Center on Disability at the Public Health Institute

# ICF: Common Areas of Function/Impairment

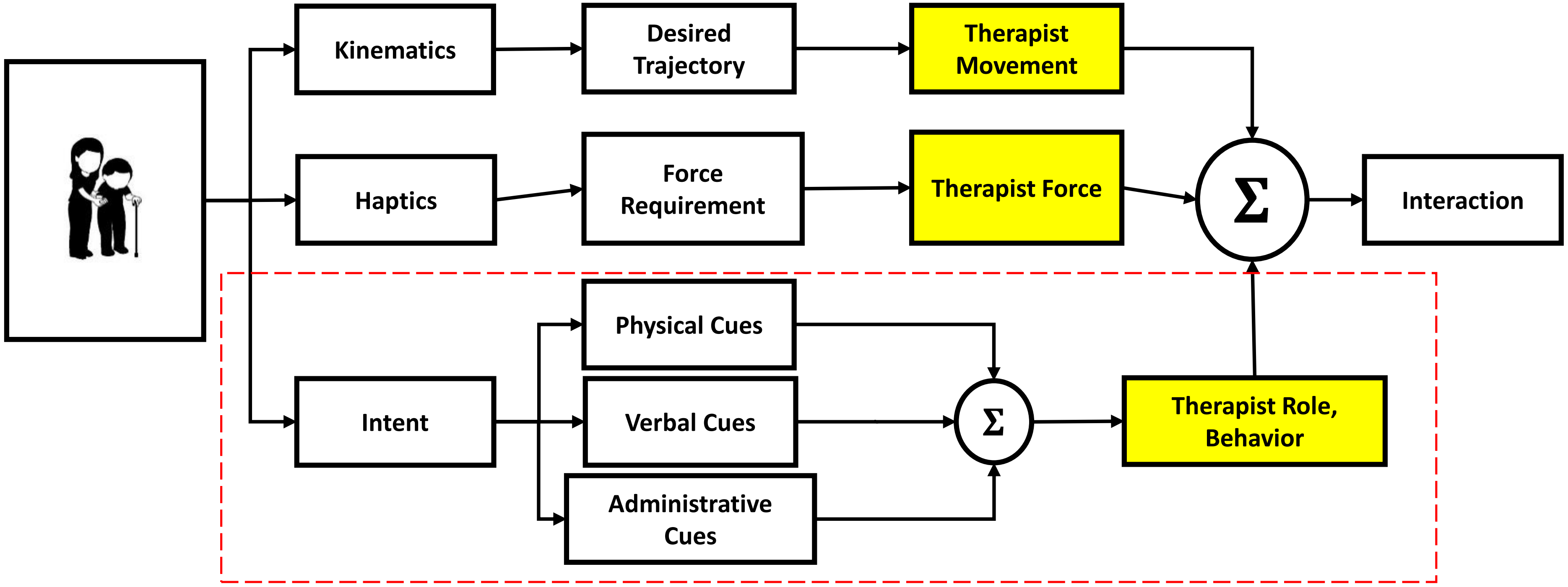
- **Cognition** – understanding & communicating
- **Mobility**– moving & getting around
- **Self-care**– hygiene, dressing, eating & staying alone
- **Getting along**– interacting with other people
    - Interpersonal Interactions
- **Life activities**– domestic responsibilities, leisure, work & school
    - Domestic Life
    - Major Life Areas
- **Participation or Community, Social and Civic Life** – joining in community activities >>



# Technology Can Bridge This Gap

# Therapy and Service Robots

# Observing Human-Human

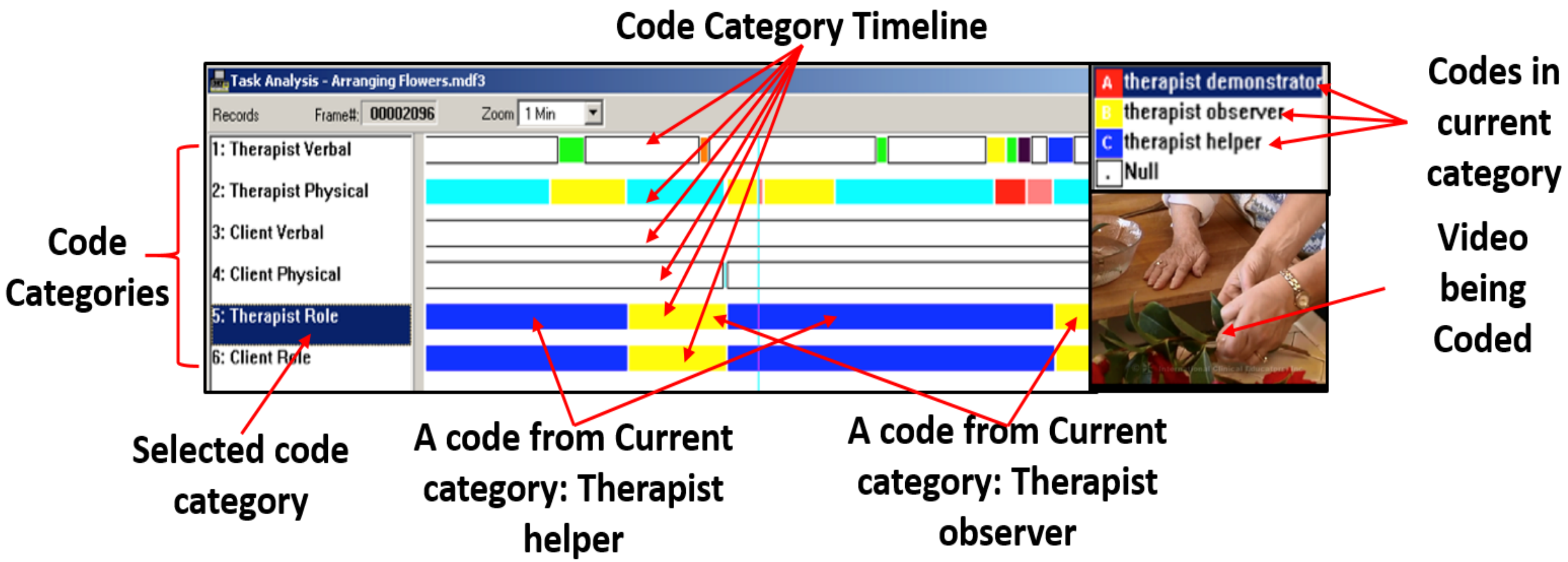



- Johnson, M.J.; **Mohan, M.**; Mendonca, R., "A Stimulus-Response Model of Therapist-Patient Interactions in Task-Oriented Stroke Therapy Can Guide Robot-Patient Interactions", *Proceedings of the Annual RESNA Conference*. New Orleans, 26-27 June 2017.

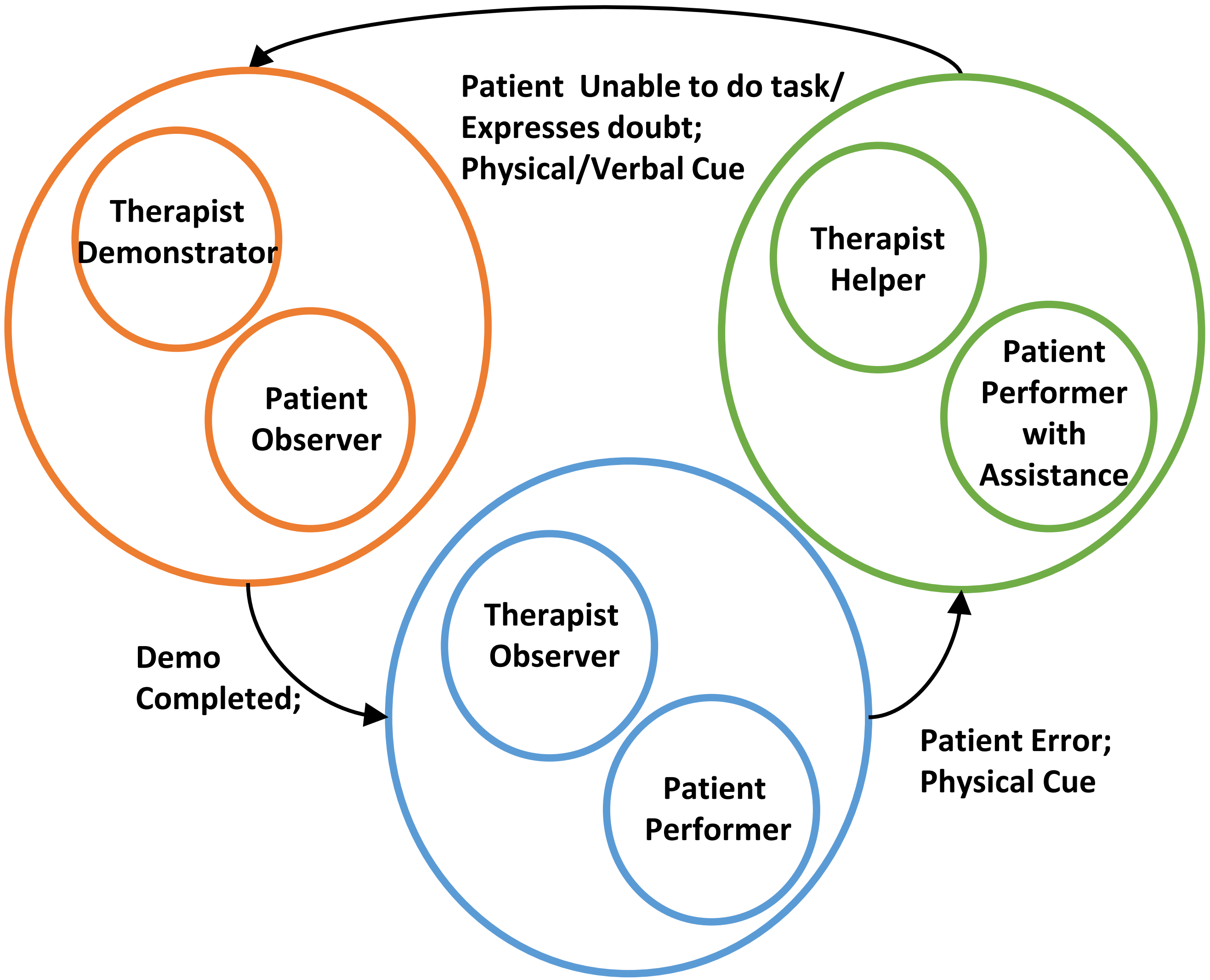
# Therapy Session

# Capturing Roles and Cues

- Multimedia Video Analysis Software: MVTA
- 8 Videos Coded independently by 2 therapists



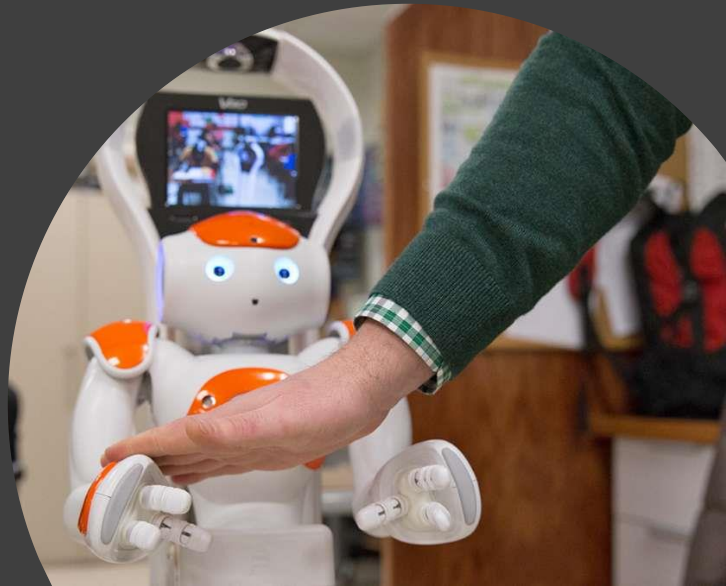
# Modelling Intent




Johnson, M.J.; **Mohan, M.**; Mendonca, R., “A Stimulus-Response Model of Therapist-Patient Interactions in Task-Oriented Stroke Therapy Can Guide Robot-Patient Interactions”, *Proceedings of the Annual RESNA Conference*

# Therapist >> Robot

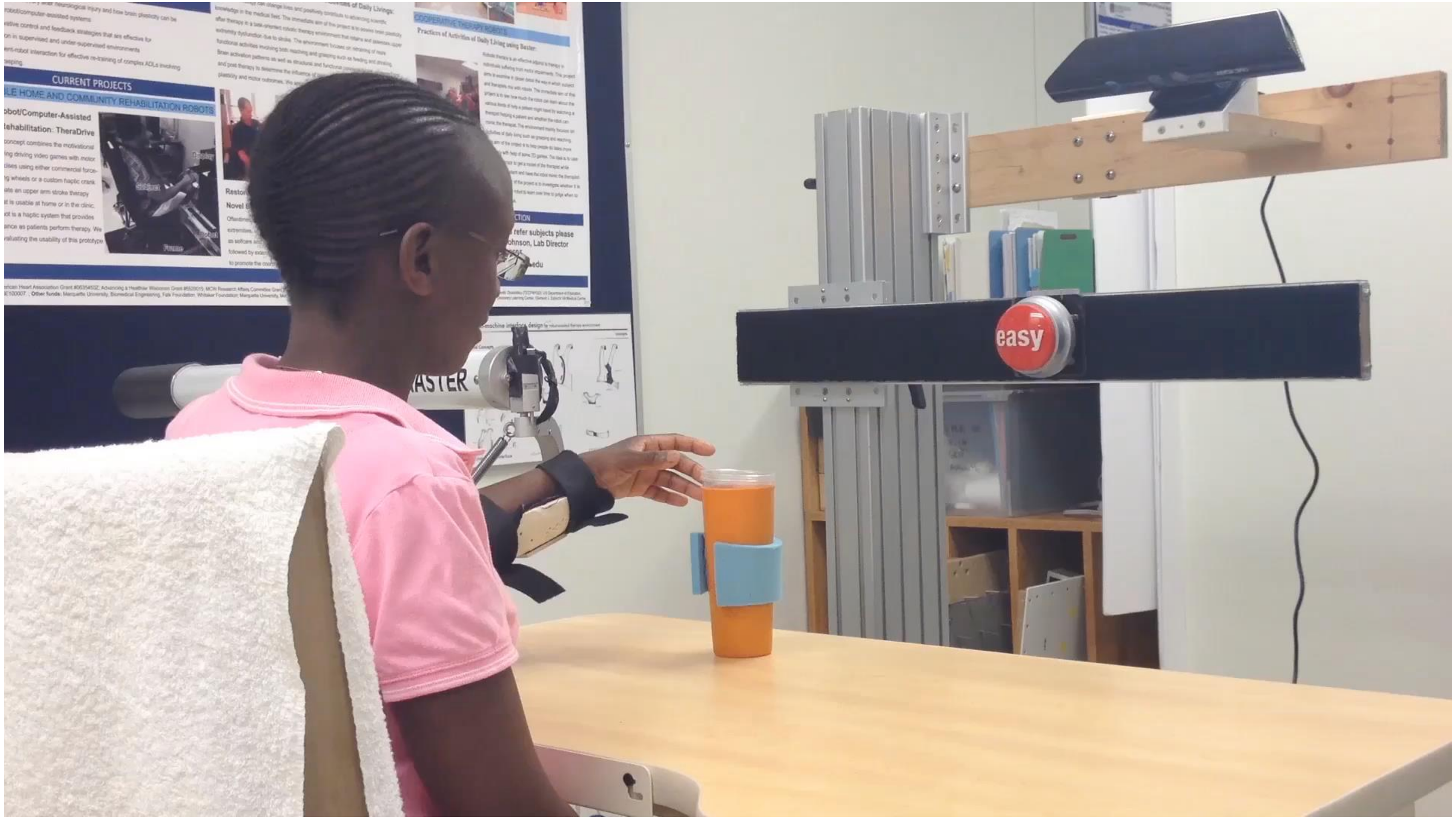
- Ideally the robot should take on three roles as demonstrator, observer and helper and co-act with the patient
- Helper role is often seen in hands-on effector THERAPY ROBOTS (e.g., ADLER, Theradrive)
- Demonstrator and Observer Roles are often found in ASSISTIVE ROBOTS or SERVICE ROBOTS (e.g. Nao)
- Fluid transitioning from contact to non-contact with a patient is not often done due to huge safety concerns about soft and hard impacts.



# Therapy Robots

- Originally developed to treat neurological disorders such as stroke and cerebral palsy.
  - Function to automate and deliver autonomous or semi-autonomous therapy for arm (or leg or joint)
  - Function to assess level of disability and impairment remaining in a limb arm (or leg)
  - Outcome >>> reducing motor impairment, increasing function and driving brain re-organization
- Currently being developed to treat a variety of diseases and disorders, e.g., Multiple Sclerosis
- Typically function in clinics or supervised settings

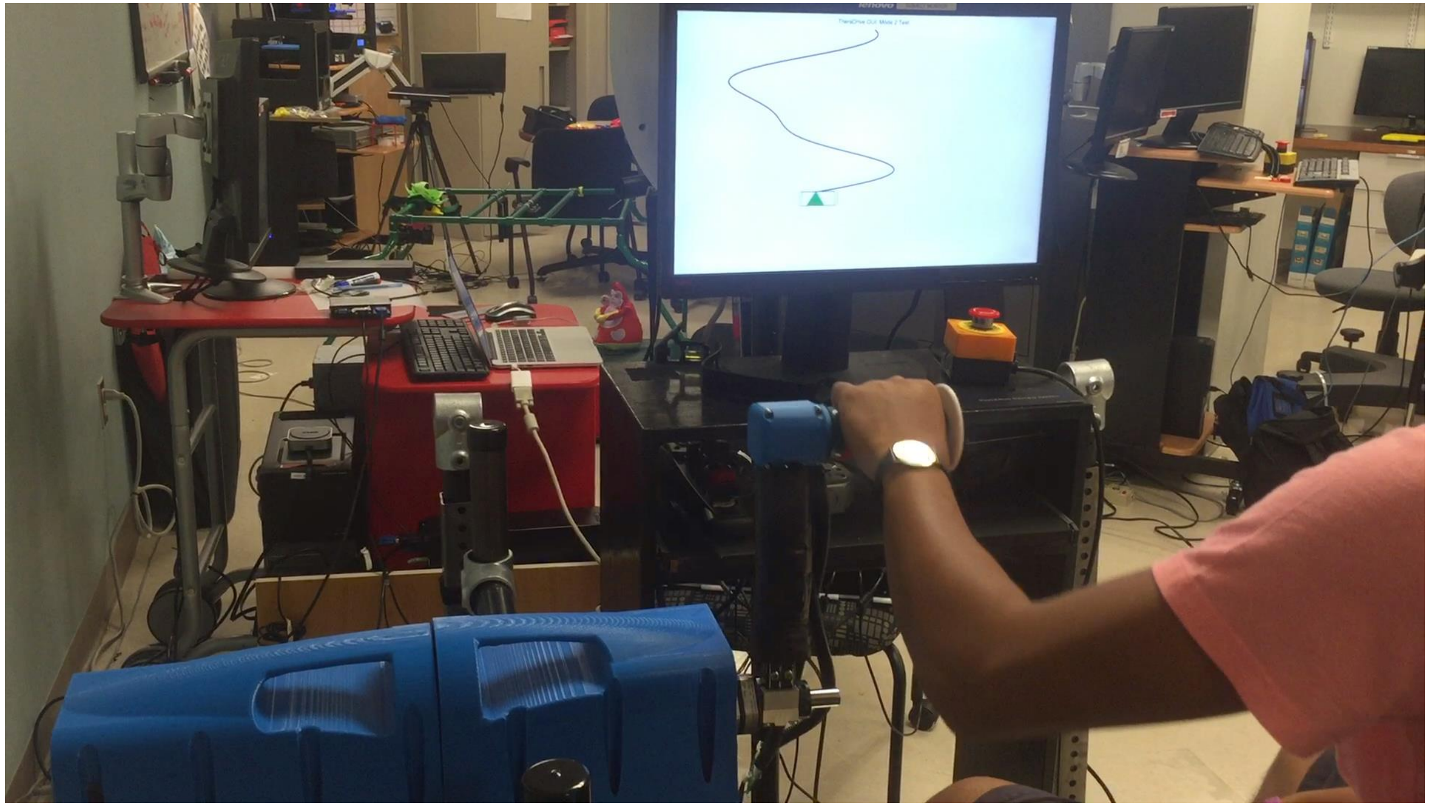
# Helper role >> ADL Exercise Robot




Johnson, M. J., Wisneski, K. J., Anderson, J., Nathan, D., & Smith, R. O. (2006, February). Development of ADLER: The activities of daily living exercise robot. In *Biomedical Robotics and Biomechatronics, 2006. BioRob 2006. The First IEEE/RAS-EMBS International Conference on* (pp. 881-886). IEEE.

# Haptic TheraDrive

- Single Degree of Freedom Robot
- Assessment Metrics:
  - Root Mean Square Error (Accuracy)
- Gaming



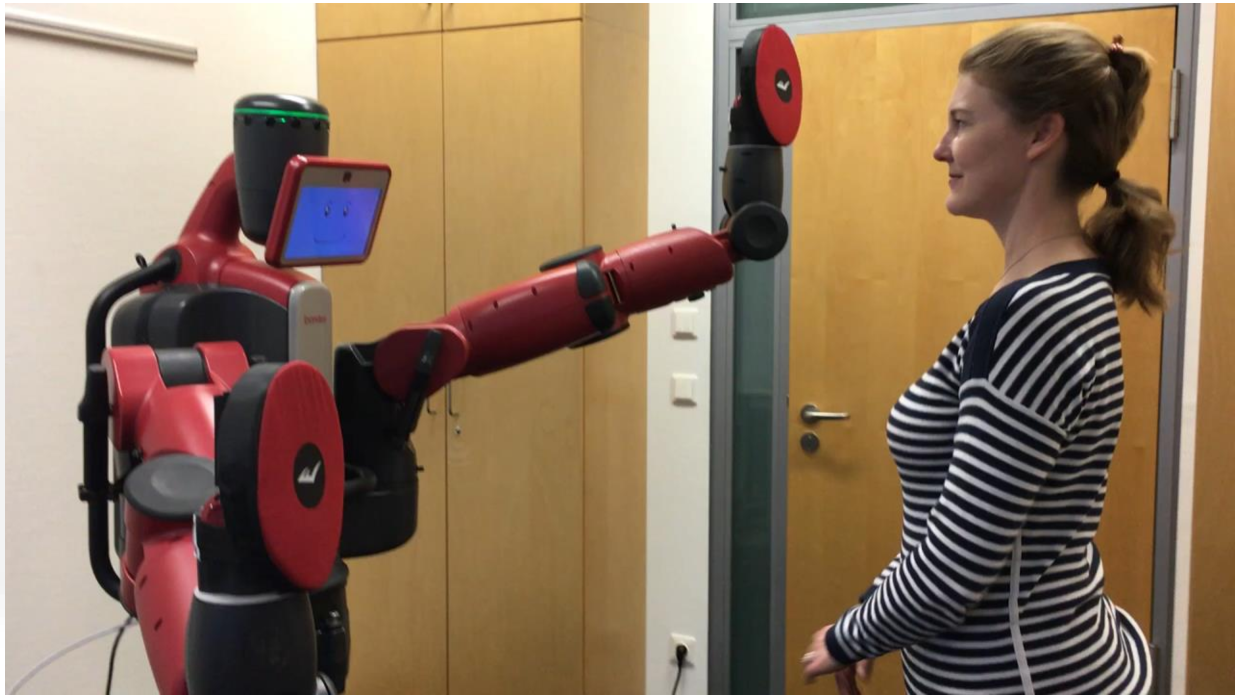
*Michelle Jillian Johnson, Roshan Rai, Sarath Barathi, Rochelle Mendonca,andKarla Bustamante-Valles: Affordable stroke therapy in high-, low- and middle-income countries: From Theradrive to Rehab CARES, a compact robot gym. Journal of Rehabilitation and Assistive Technologies Engineering. sagepub.co.uk/journalsPermissions.nav, 4: 1-12, May 2017 Notes: DOI: 10.1177/2055668317708732.*

# Assistive Robots = Service Robots in Rehabilitation/Medical Settings

- Replace other functions or activities or things (e.g. surveillance robots)
- Replace a loss limb (e.g., prosthetics)
- Replace the function of a paralyzed limb and do tasks instead of the limb (e.g., wheelchair robot)

# Demonstrator/Observer roles >>

## Baxter: Elder Exercise

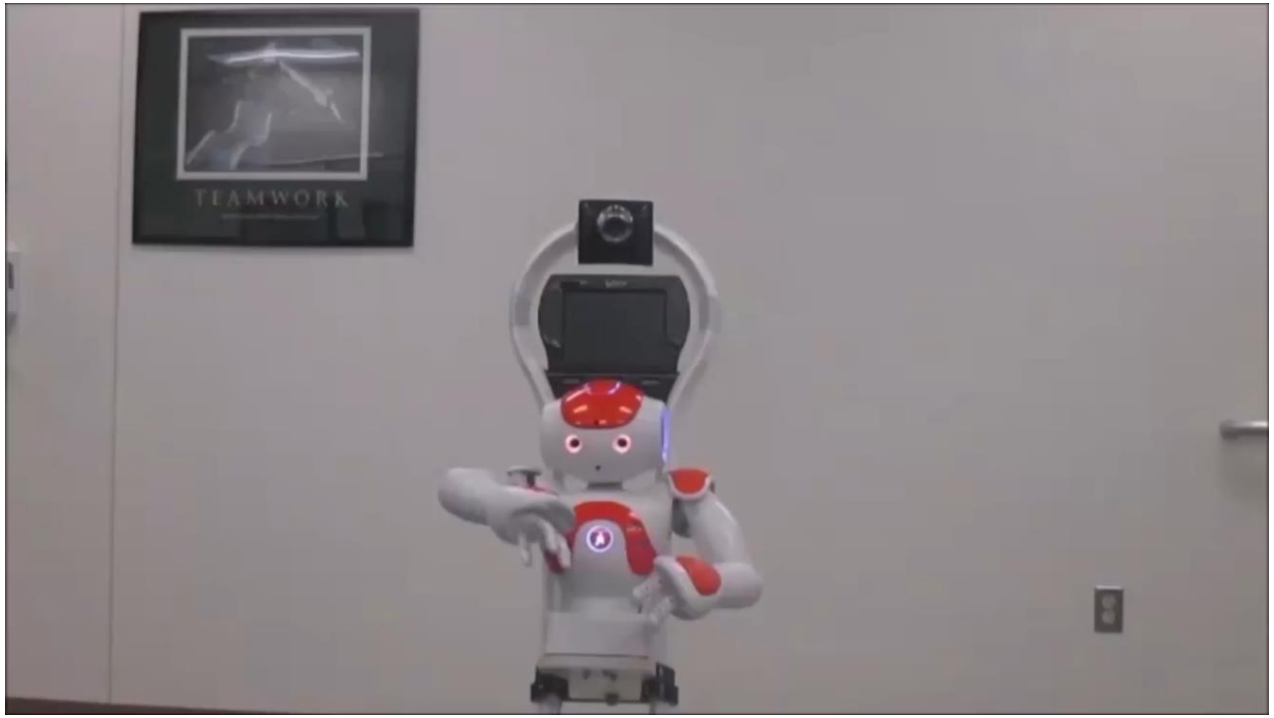


*Naomi T. Fitter, Dylan T. Hawkes, Michelle J. Johnson, and Katherine J. Kuchenbecker, Designing Human-Robot Exercise Games for Baxter, IROS late breaking 2016*

- Collaboration with Dr. Kuchenbecker and Dr. N Watts
- Elder Exercise Care

# Demonstrator role >>

## Flo: Mobile Therapist




- Combination of two off the shelf robots (Nao and VGo)
- Designed to provide remote and in-person “hands off” therapy

# Therapy and Service Robots for Elders in the Community

# Living Independently for Elders – A Mercy LIFE Center

- Community-based setting
- All-inclusive care
    - Clinical care
    - Rehabilitation care
    - Doctors, Nurses, Therapists, Caregivers
- Elders > 65 age
- Elders have various levels of function
- Medicare/Medicaid
- 80% African American
- 75% Female
- GOAL >> MAINTAIN ELDERS INDEPENDENCE


- NSF Partnerships for Innovation: Building Innovation Capacity program (Grant #1430216; IIP-1430216).
- Rehab Robotics Lab, MOD Lab (Dr. Yim, PI), Penn Nursing (Dr. Cacchione), Savioke, Inc. (Dr. Lau)

# Activity and Participation >> Independence

- Activity is a execution of a task or activity by the elder
- Participation is involvement in a life situation
- Impairment >> Activity Limitation >> Participation Restrictions
- Participation promotes inclusion in life activities in the context of the persons community
- External factors such as social roles, social environment, political environment, physical environment, psychological environment may lead to activity limitations and participation restrictions and therefore independence reduction.

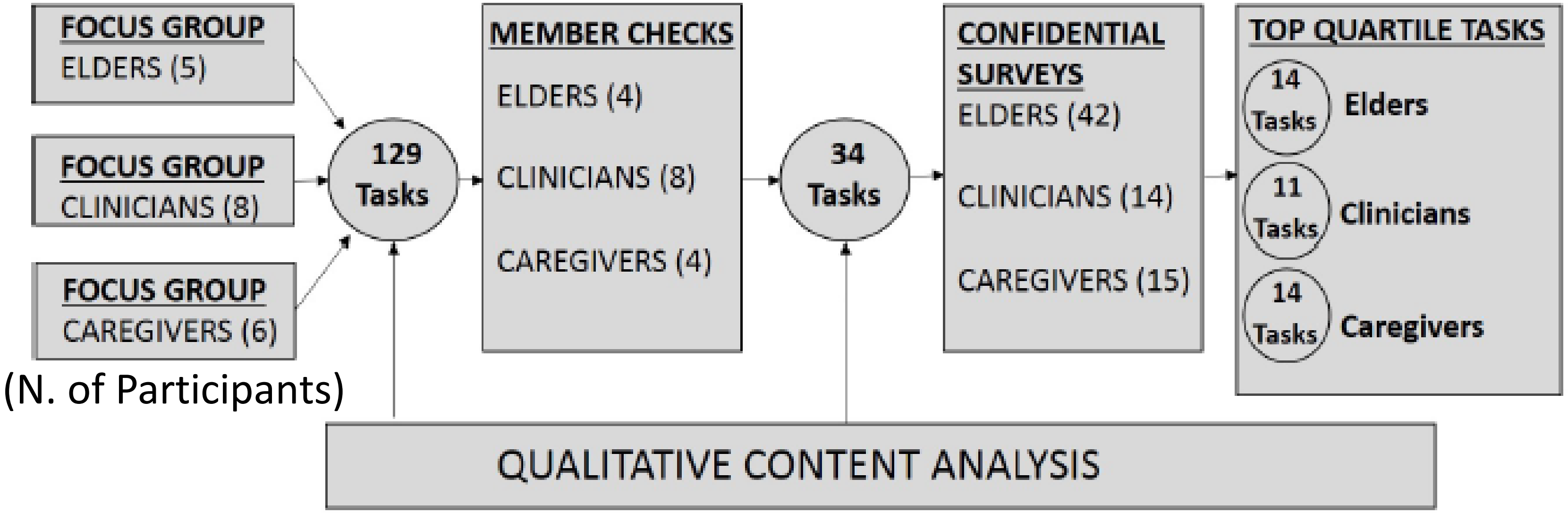
Ref: PM&R Secrets 2nd Edition and ICF ref

# Can we develop an affordable social robot that can support elders at the LIFE center?

< $20,000, Mobile, Manipulates

What tasks should it do?

# Pre-Deployment Data Acquisition: A Multi-Method Approach*




| | Rank |
|---|---|
| Having additional assistance when pain flares up | 1 |
| Outings (shopping, supermarket) | 2 |
| Having your food preference known | 3 |
| Getting a drink | 4 |
| Being asked about your preference | 5 |
| Assistance with being in bed (change position, putting on blanket) | 6 |
| Having caretakers help keep spirits up | 7 |
| Reaching things on high shelves | 8 |
| Getting around in a wheelchair | 9 |
| Walking | 10 |
| Games (Bingo) | 11 |
| Caretakers help to increase socialization opportunities | 12 |
| Having clothes taken out | 13 |
| Assistance finding items in closet | 14 |

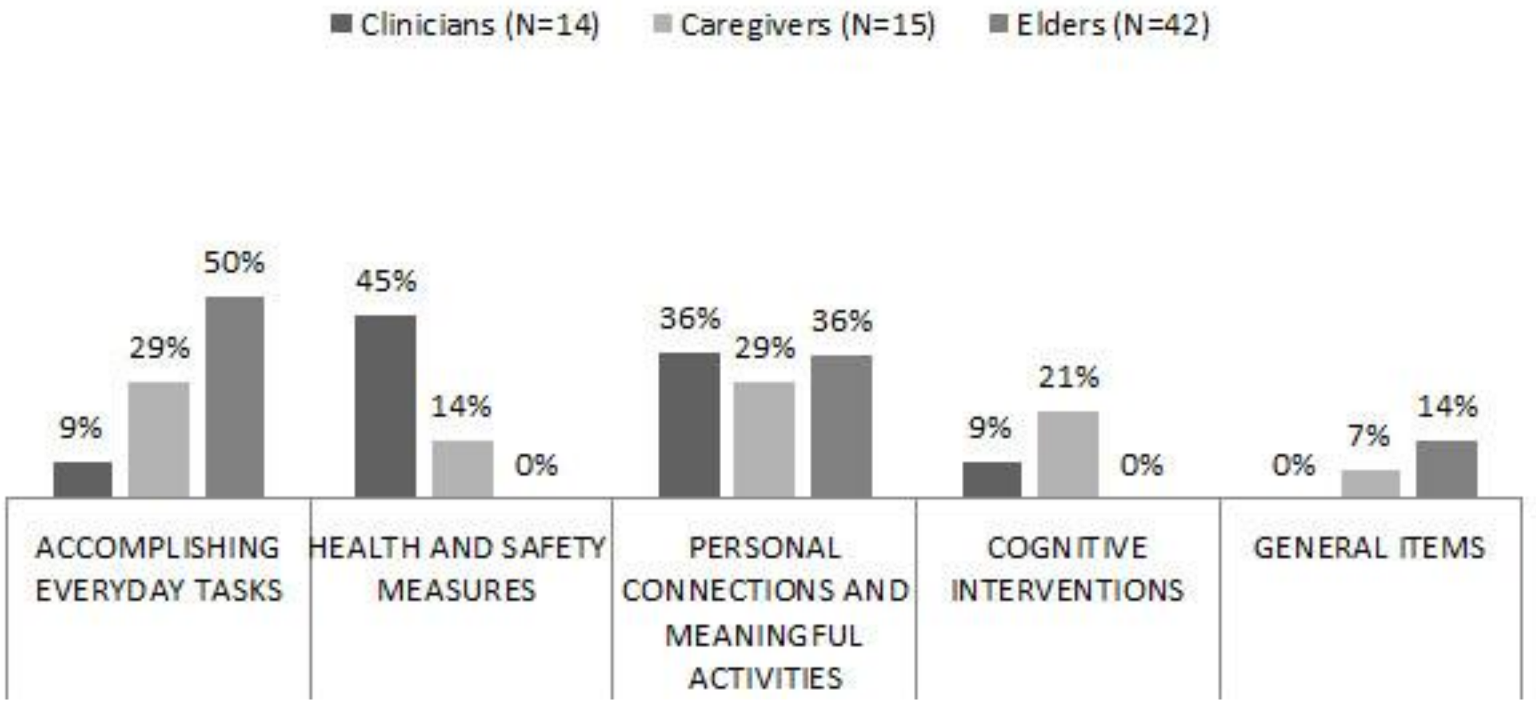
* J. Sefcik, M. Johnson, M. Yim, T. Lau, N. Vivio, Caio Mucchiani, Pamela Z. Cacchione, **"Stakeholders' Perceptions Sought to Inform the Development of a Low-Cost Mobile Robot for Older Adults: A Qualitative Descriptive Study ",** in Clinical Nursing Research, Sept. 2017.

# Elder Care: Low-Cost Assistive Mobile Robot

Int J of Soc Robotics
DOI 10.1007/s12369-017-0436-5
CrossMark

**Task and Design Requirements for an Affordable Mobile Service Robot for Elder Care in an All-Inclusive Care for Elders Assisted-Living Setting**

Michelle J Johnson[1] · Megan A. Johnson[2] · Justine S. Sefcik[3] · Pamela Z. Cacchione[4] · Caio Mucchiani[5] · Tessa Lau[6] · Mark Yim[7]

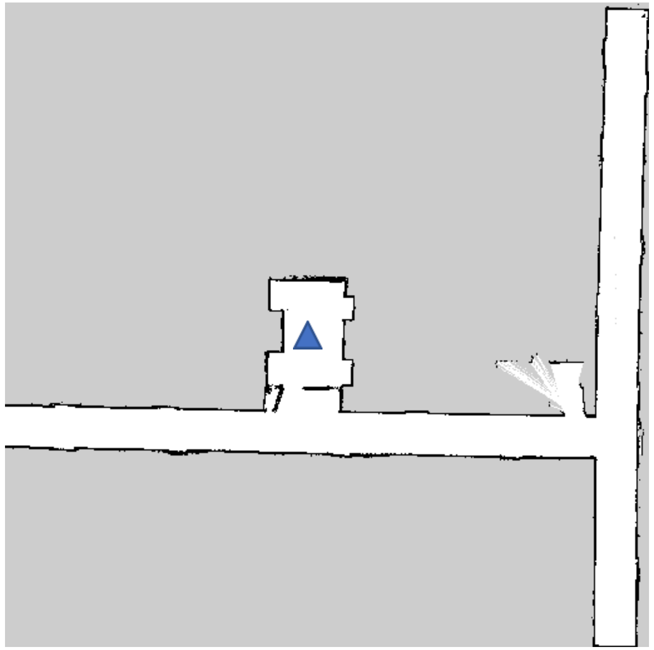


# System Description: Savioke Hardware


<u>Specifications</u>:

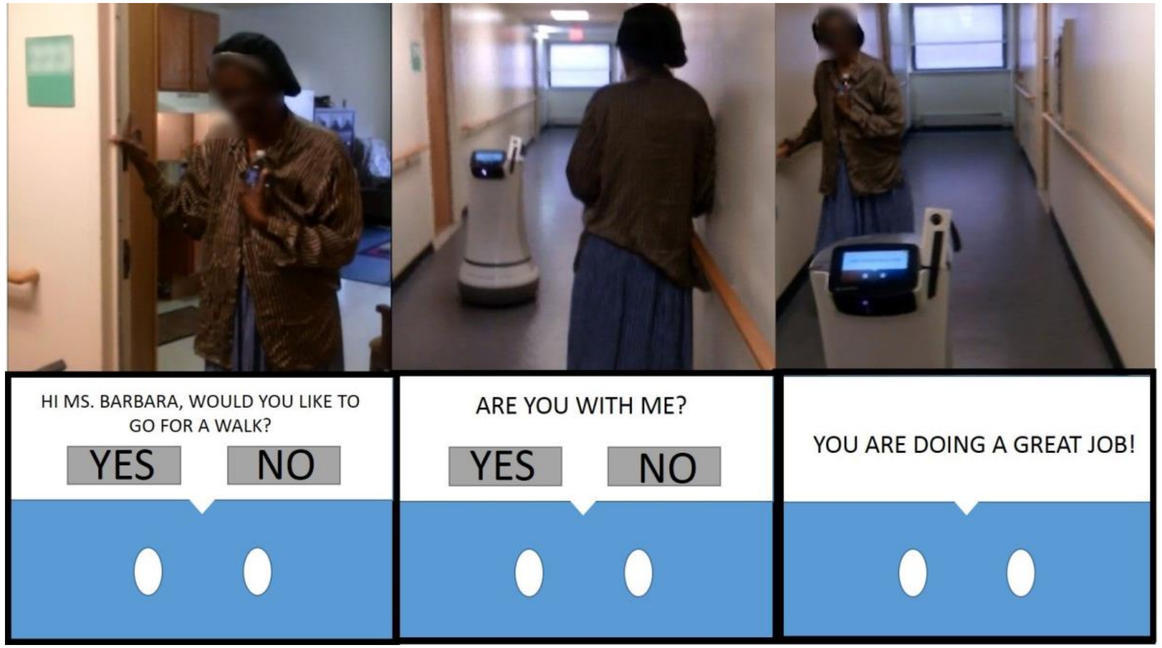
- 177mm touchscreen monitor, storage bin
- Navigation: Lidar and sonar sensors
- Speakers added for enhancing interaction
- Camera for recording the interaction





# Mobile only Deployments*

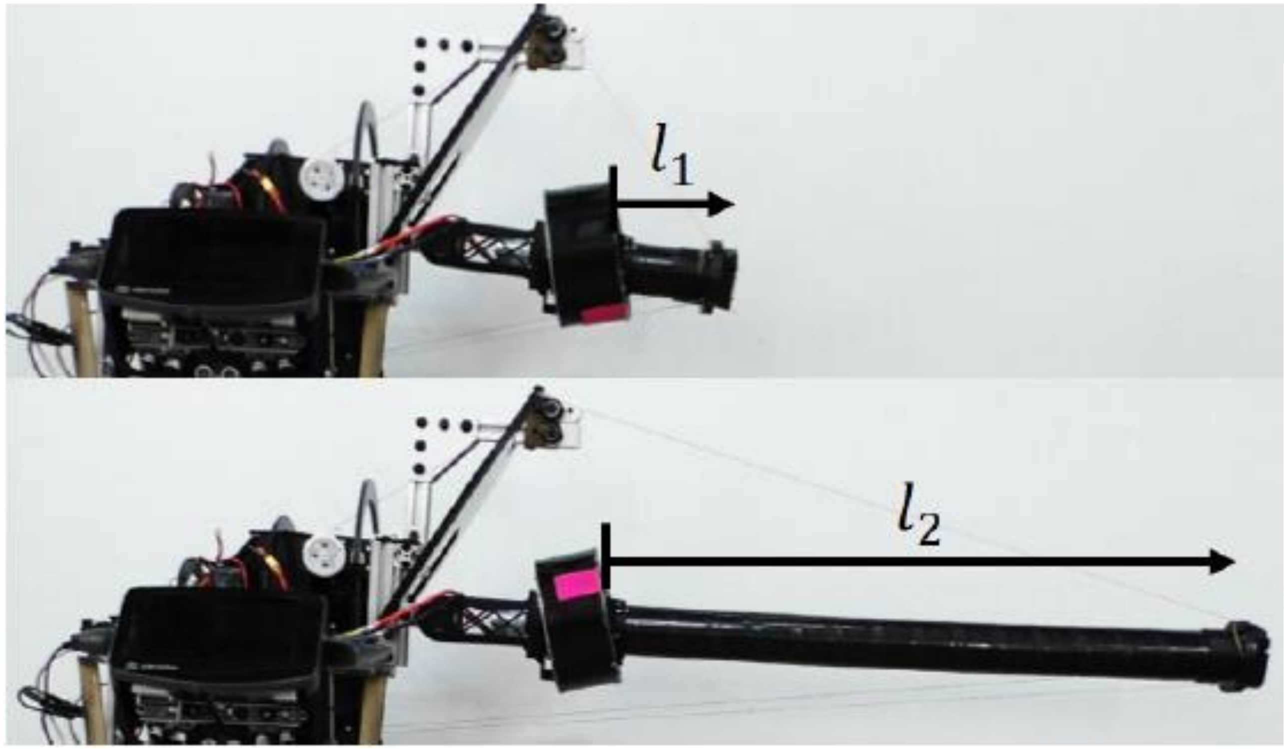
Autonomous Hydration reminder and Water delivery



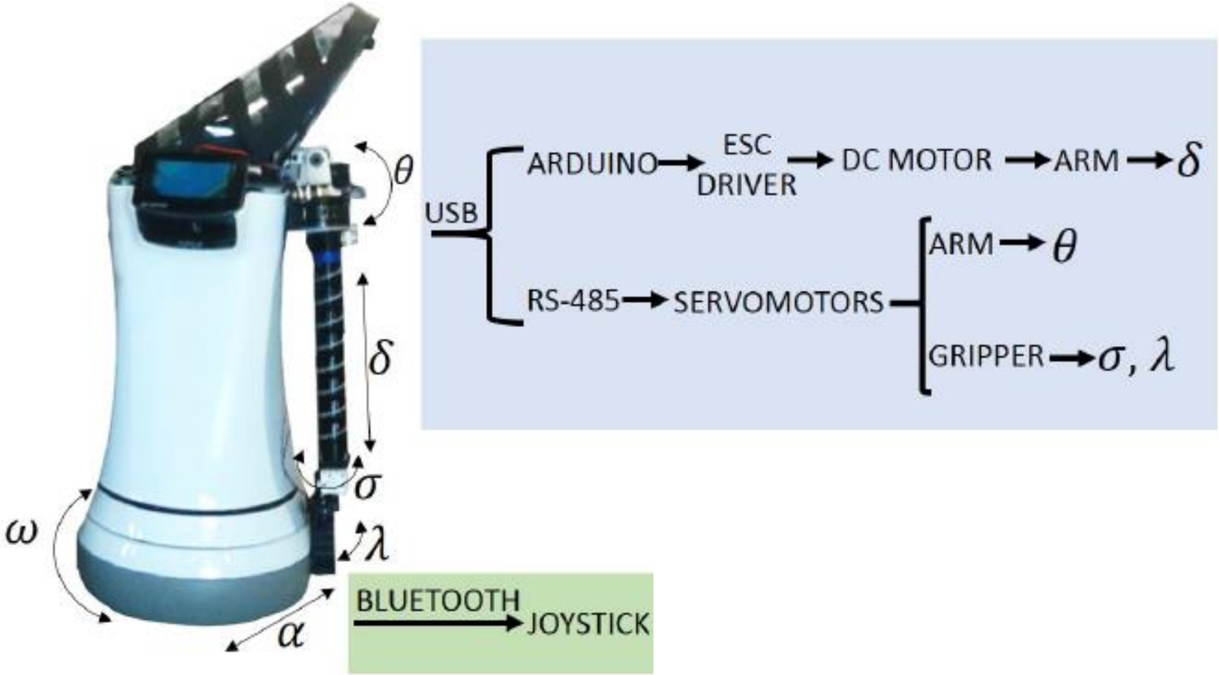

Walking encouragement

***Mucchiani C, Sharma S, Johnson M, Sefcik J, Vivio N, Huang J, Cacchione P, Johnson M, Rai R, Canoso A, Lau T.** 'Evaluating older adults interaction with a mobile assistive robot' In IEEE/RSJ International Conference on Intelligent Robots and Systems, **IROS 2017**.

# System Description: Mod Lab's Manipulator

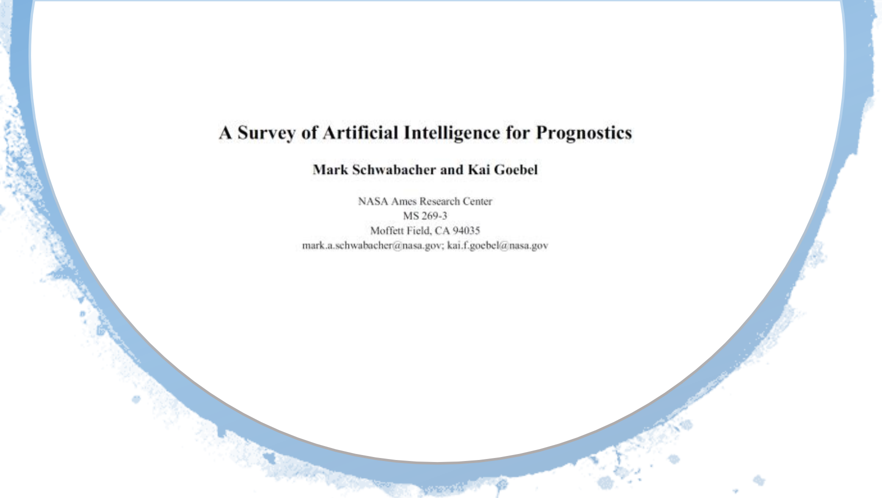



$(l_1 = 20cm, l_2 = 80cm)$



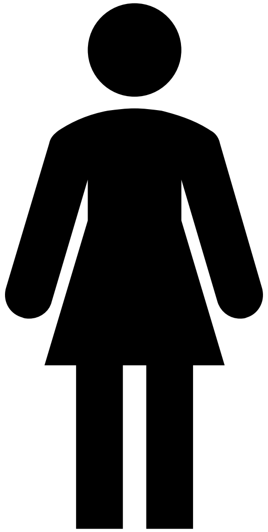
# Reaching Objects/Corn Toss Games

# Therapy and Service Robots as Integrated System Health Managers


A Survey of Artificial Intelligence for Prognostics

Mark Schwabacher and Kai Goebel

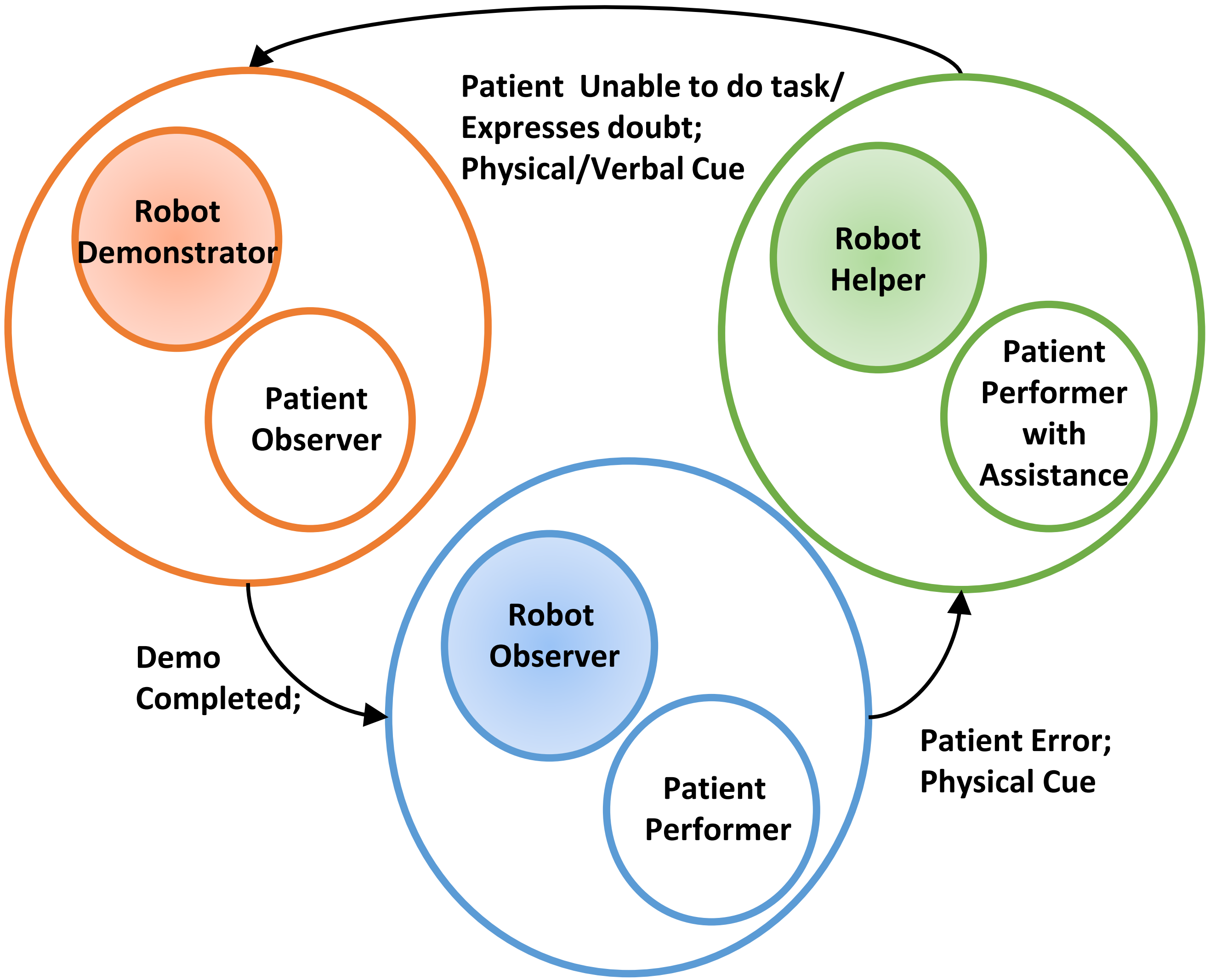
NASA Ames Research Center
MS 269-3
Moffett Field, CA 94035
mark.a.schwabacher@nasa.gov; kai.f.goebel@nasa.gov



# Integrated Systems Health Management

- Fault detection (detecting that something is wrong)
- Fault Diagnostics (isolation & identification)
  - Fault isolation (determining the location of the fault)
  - Fault identification (determining what is wrong; that is, determining the fault mode)
- Fault prognostics (determining when a failure will occur based conditionally on anticipated future actions)

# Scenario 1: Fully Autonomous Robot




Johnson, M.J.; **Mohan, M.**; Mendonca, R., "A Stimulus-Response Model of Therapist-Patient Interactions in Task-Oriented Stroke Therapy Can Guide Robot-Patient Interactions", *Proceedings of the Annual RESNA Conference*

# Autonomous Robot Guidelines

- Assist the elder with tasks
- Monitor the elder actions
- Provide either physical or verbal feedback based on user performance
  - Physical assistance if provided should be safe
- Able to modify level of robot involvement required for task
- Able to track individual elders and group of elders
- Able to communicate with elder - preference
- Able to switch out of HELPER to either OBSERVER OR DEMONSTRATOR modes
- Monitor the elder health over time
- Alert clinicians, medical doctors and caregivers to decline
- Suggest actions/tasks to elder increase activity and social engagement

# Fault detection (detecting that something is wrong)

- Monitor unusual function in key domains
  - Heart rate – Pulse Oximeters
  - Pain levels – Visual Analog Scales
  - Exertion levels – Borg Scales
  - Emotional levels – Face expression and Galvanic Skin Function
  - Gait – stride length
  - Location – GPS
  - Social activity – calls, visits, level of contact with others
  - Communication – responsiveness
  - Brain activity - EEG
  - Range of Motion – joint sensors, 3D motion capture
  - Body kinematics - 3D motion capture
  - Muscle kinetics - EMG
  - etc
- What are the threats to independent function in key domains: Cognition, mobility, hearing, vision etc.?

# Fault Diagnostics (isolation & identification)

- Fault isolation (determining the location of the fault)
  - Gather periodic clinical/therapy data from records
  - Gather data on adverse events – e.g., falls, hospitalization,  ER visits
  - Gather robot-interaction data
  - Measure current function in the key domains including medical to learn unusual changes
  - Isolate areas impacted
- Fault identification (determining what is wrong)
  - Compare current function to past functional levels
  - Isolate anomaly

# Fault Prognostics (determining when a failure will occur based conditionally on anticipated future actions)

- Define elder typical actions over time
- Define elder frequency of adverse events – e.g., falls, hospitalization, ER visits
- Increase robot interaction/actions to probe for possible deviations
- Define group actions over time

# Possible Barriers to Acceptance of Scenario 1

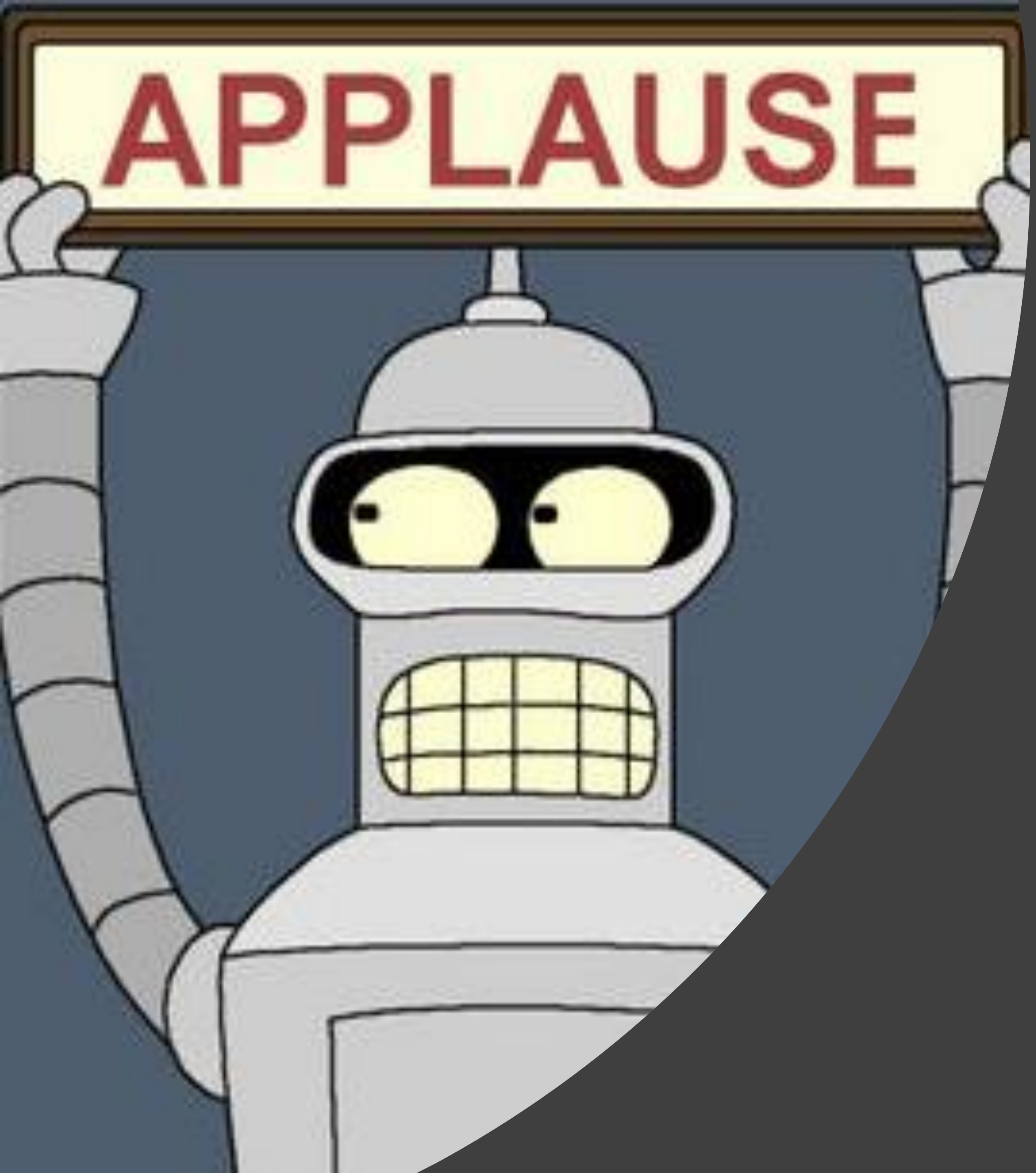
- Robot replaces human contact and may seem impersonal
  - Human does motivation and psychological aspect of therapy
- Robot interaction with human must be VERY safe
- Robot will not be as good as therapist
- Robot may not be versatile to monitor more than one human >>> alone or in groups
- Robot may not be able to easily obey privacy and security rules
- Requires human to wear sensors

# Questions

- What are best strategies for overcoming barriers and creating an ACCEPTABLE Therapy/Service Robots that can do IHSM?
- How do we overcome barriers of low number of data?
- How do we juggle the need to track the individual AND the group?
- How can the Therapy/Service Robots that can do IHSM do SHARED management?

# Acknowledgements


- Council of Elders at the PACE and SAL staff and members at LIFE center
- National Science Foundation (NSF) Partnerships for Innovation: Building Innovation Capacity program under Grant No. 1430216; IIP-1430216
- National Institutes of Health: NICHD Grant No. R21 HD084327-01 grant
- NSF Louis Stokes Alliances for Minority Participation Grant, CURF Vagelos Undergraduate Research grants
- University of Pennsylvania – Center for Healthcare Technology Pilot Grant 2018
- Mexican Grants
  - El Comite' Technico y de Administracion del Fondo Mixto CONACYT-Goberno del Estado de Chihuahua CHIH 2009-CO2-127781 entitled "Gimnasio Robotica";
  - CONACYT I0015-225083.
- American Heart Association Grant #0635450Z
- NIH K25 Grant #1K25NS058577 – 05
- Research supported by RERC Technologies for Children with Orthopedic Disabilities (TECP4POD): US Department of Education, NIDRR H133E100007
- Departmental funds of the Physical Medicine and Rehabilitation of the University of Pennsylvania




# QUESTIONS?