Why Adaptability, Affordability, and Autonomy are Important Considerations for Rehabilitation Robots and Assistive Technology for 21st Century Older Adults?

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Presentation at International Expert-Conference on Human Rights of older Persons

12 – 13 NOVEMBER 2018, CONFERENCE ROOM RINGTURM, SCHOTTENRING 30, 1010 VIENNA

Consequence of Age and Diseases

- About 700 million people, or 10 per cent of the world's population, are >60 age
- By 2050, the # of older persons will have doubled reaching 20%
- …often leads to…disability and decreased independence
- Major factors causing disabilities world wide
  - Diabetes >>> Amputations and Blindness
  - High Blood Pressure >> Strokes
  - HIV >> Dementia, Strokes
  - Cancers >> Brain Injury, Spinal Injury
  - Road Injury >> Spinal Injury, Brain Injury
  - Neonatal Nutrition >> Premature Births >> Cerebral Palsy, Autism, Down Syndrome etc.

Technology Can Bridge This Gap

Three Design Considerations

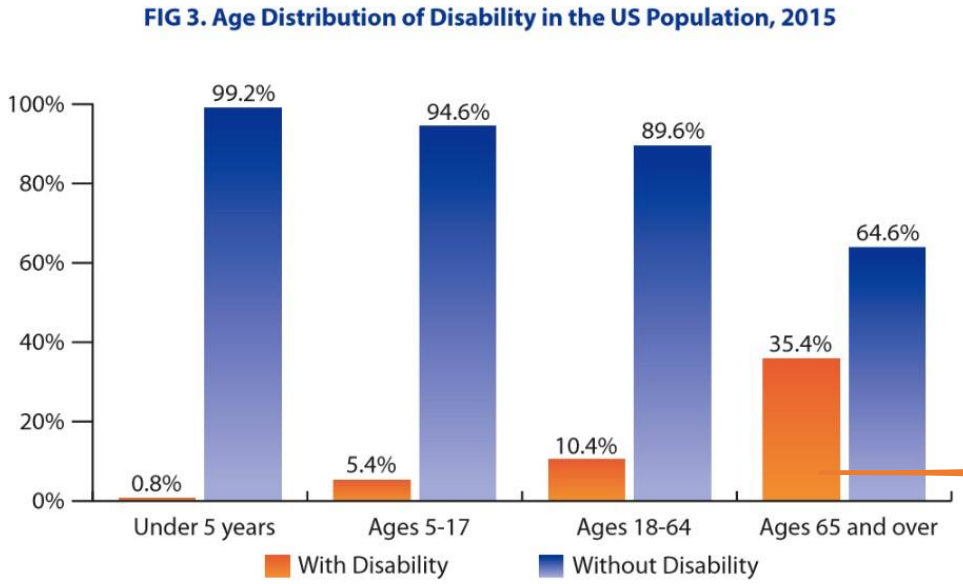
Adaptability

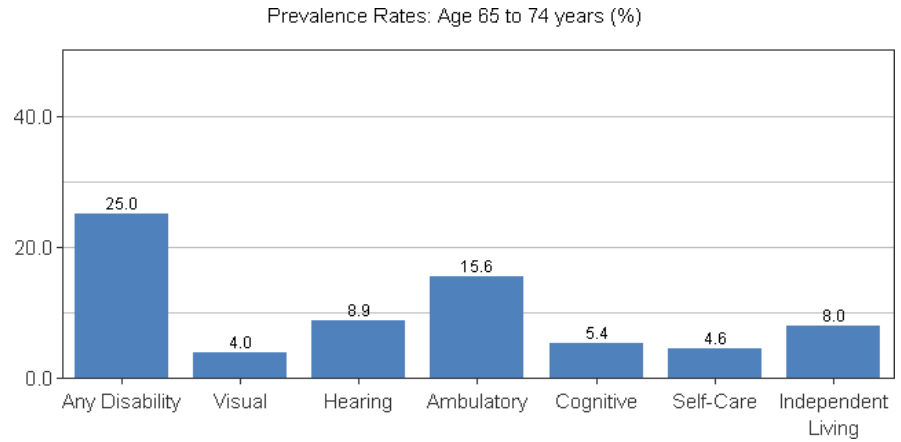
Affordability

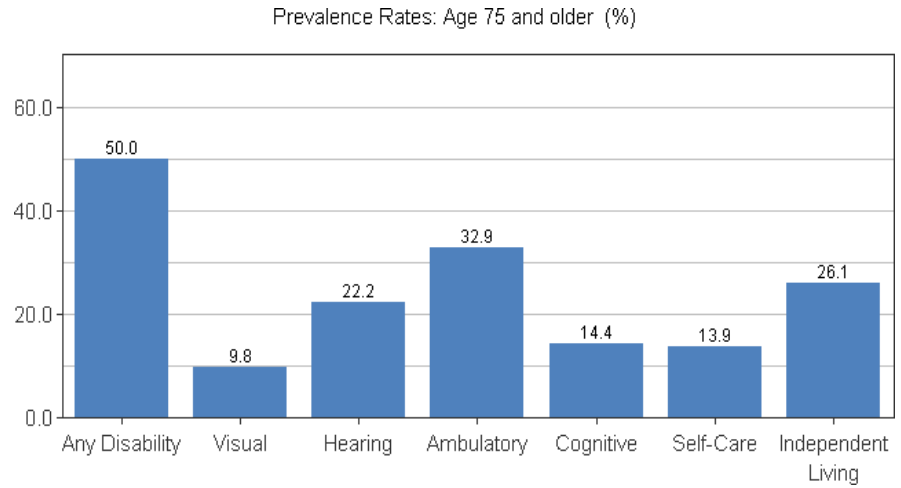
Autonomy

Adaptability

- Older persons are not a homogenous group
  - Active Elders
  - Frail Elders
  - Disabled Elders
- Older persons may develop different types of impairments
- Robots and Technology MUST adapt to changing needs considering cultural and social context





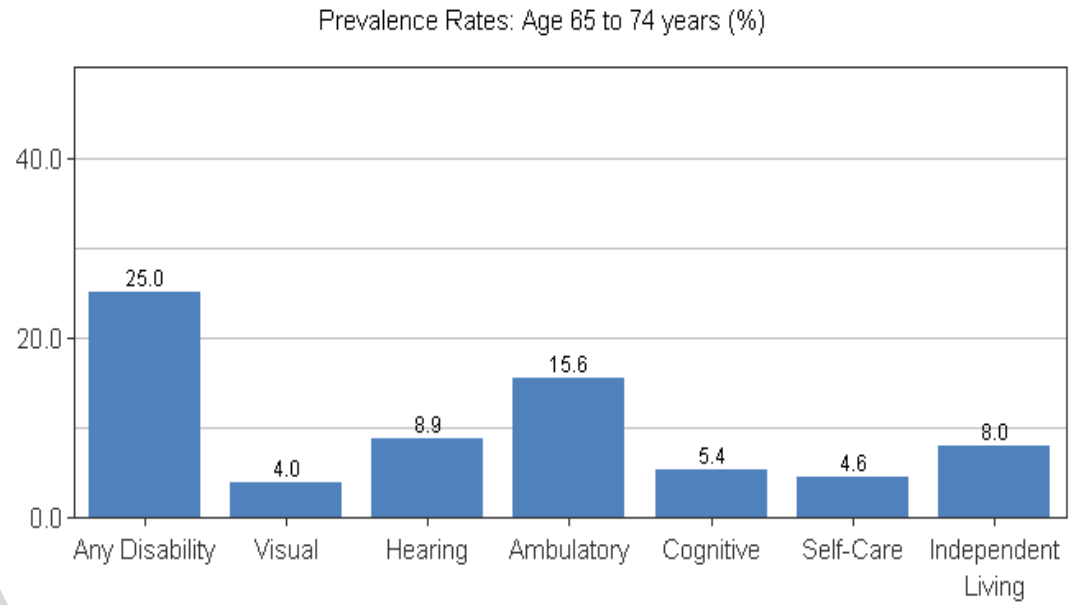


Disability and Age: USA

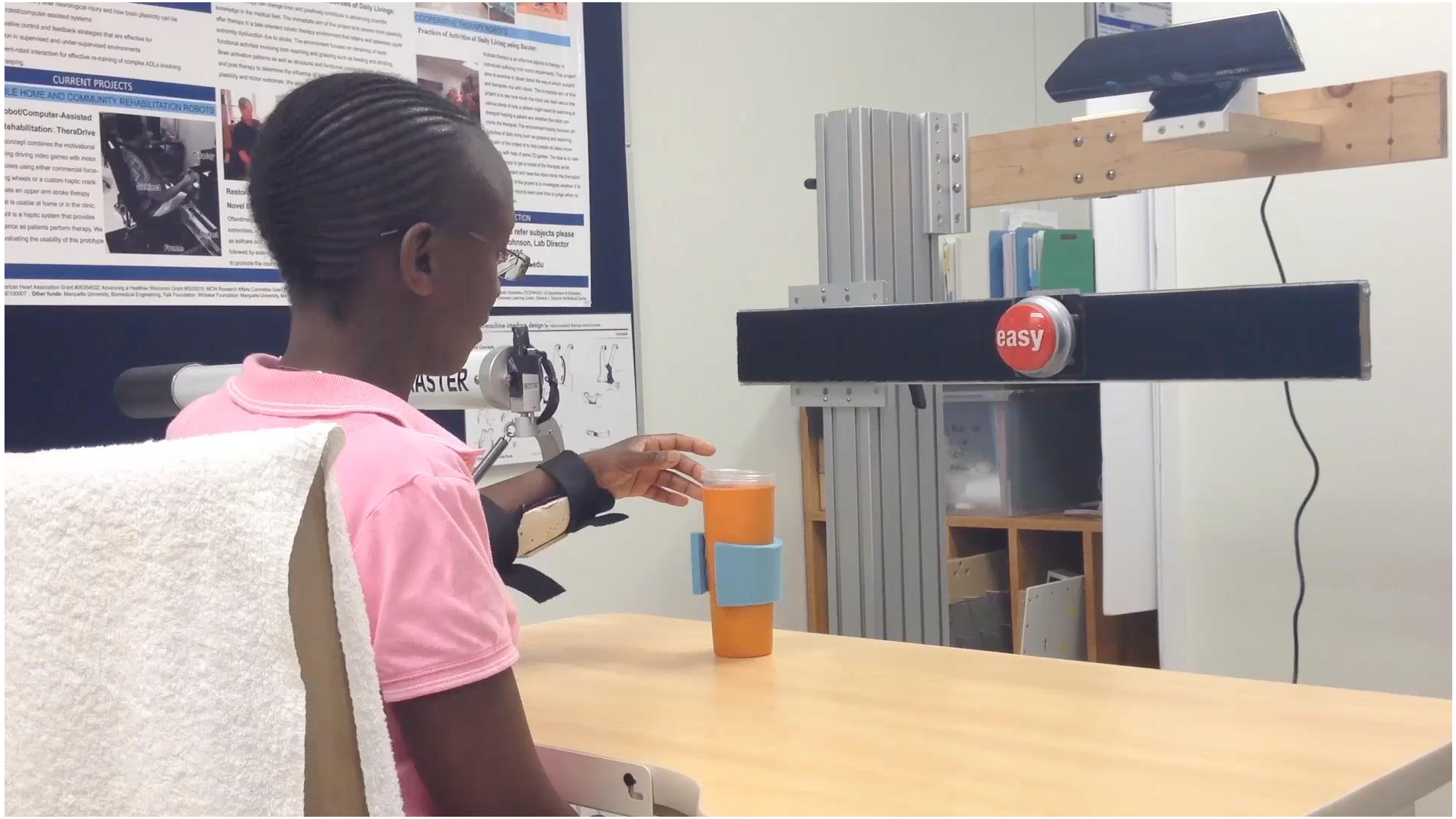
Ref: 2016 Disability Statistics
by Lewis Kraus, MPH, MCP at the Center on Disability at the Public Health Institute

Robot/Technology must consider 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 >>



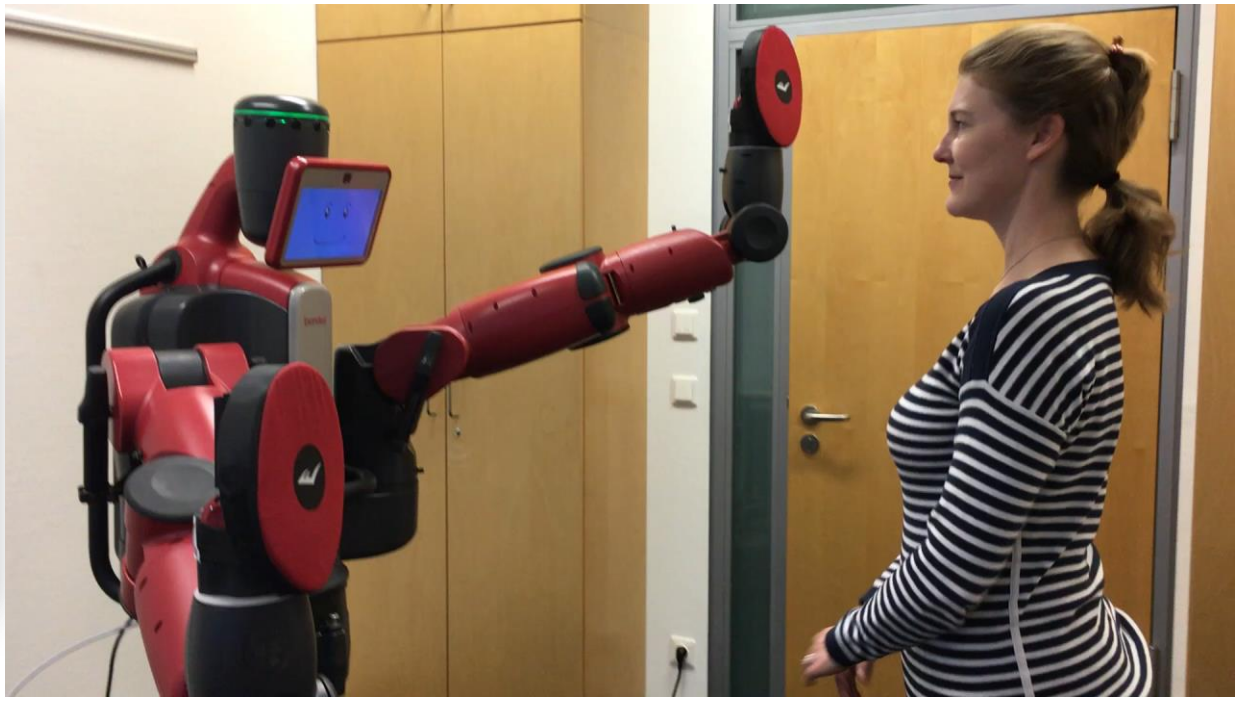
ADL Exercise Robot



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.

Myomo Pro

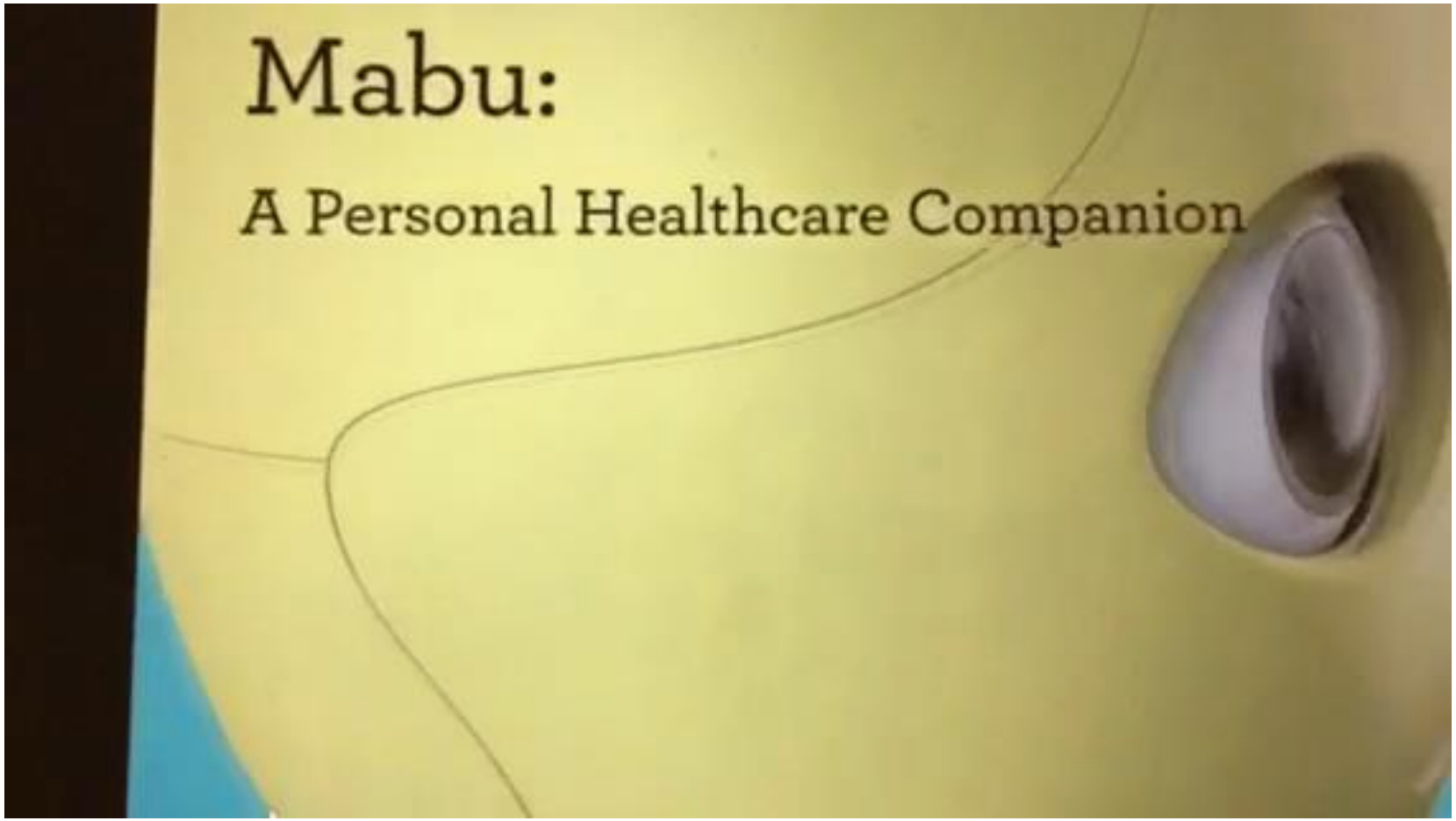
Baxter: Elder Exercise



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

Mabu: Chronic Disease Management



- https://vimeo.com/130560599

By Catalina Health

Affordability

- Two of the world's older people live in low-and middle-income countries and this proportion will rise to 80% by 2050
- Older persons live in diverse settings
  - In homes by themselves
  - In homes with family
  - In nursing homes
  - In assisted living setting
- Rehabilitation now taking place in diverse settings
  - Hospitals
  - At home with nursing care or a home health agency
  - Nursing home
  - Day-care or all inclusive care facility (PACE)
  - Assisted Living Facility
- Robots and Technology MUST become Affordable considering the settings in which they are applied

Care/Rehabilitation in Low-Resource Settings

- Diversity of settings
- Low resources >> Cost
- Little Space
- Rehabilitation care is not as specialized and many are not trained to deliver it
- # of Therapists/Clinicians low compared to # of Elders/Patients
- Increased diversity of patients – needs are very mixed
  - Not just stroke
  - Need system that works with other diagnoses
  - Motor and cognitive
- Increased need for remote follow-up
- Increased need to monitor compliance
- Decreased availability of rehabilitation technology or if available may not be at the same quality

Robots…

- Provide an affordable opportunity for prevention care and to extend rehabilitation/care beyond hospital for all patients
- Use technology to increase access to rehabilitation/heathcare services and advance interventions
- Use technology to stretch resources and increase efficiency of small group of clinicians in diverse rehabilitation and care settings
- Provide high-tech features at an affordable costs

* USE WHO Cost-Effective Thresholds

What is Affordable*?

Profile	Country	A = GDP/capita (USD)	B = 3*GDP/capita (USD)
High	USA	53,072	159,216
	UK	41,788	125,364
Upper-Middle	Mexico	10,307	30,921
	Jamaica	5,290	15,870
	Botswana	7,315	21,945
Low -Middle	Ghana	1,858	5,574
	India	1,499	4,497
	Veitnam	1,908	5,724

HIGHLY COST-EFFECTIVE = < A

A > COST-EFFECTIVE < B

UNREASONABLE >B

Case-Study: Affordable Therapy Robot Gym

- **Rehabilitation Robotics Lab (MCW/MU/UPENN)**

PM&R Rehabilitation Robotics Lab

- **ITESM Campus Chihuahua, Chihuahua, Mexico**

ITESM Campus Chihuahua, Chihuahua, Mexico

- **CREE: Centro de Rehabilitacion y Educacion Especial DIF NL, Chihuahua, Mexico**

CREE (Rehabilitation Hospital)

Bustamante Valles et al. Journal of NeuroEngineering and Rehabilitation (2016) 13:83
DOI 10.1186/s12984-016-0190-1

Journal of NeuroEngineering and Rehabilitation

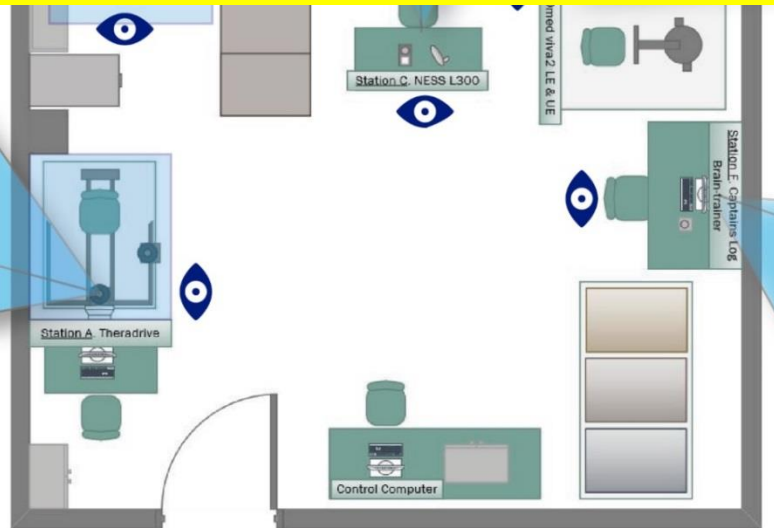
RESEARCH Open Access

Technology-assisted stroke rehabilitation in Mexico: a pilot randomized trial comparing traditional therapy to circuit training in a Robot/technology-assisted therapy gym

Karla Bustamante Valles[3,4], Sandra Montes[4], Maria de Jesus Madrigal[5], Adan Burciaga[5], María Elena Martínez[4] and Michelle J. Johnson[1,23*]

20 Stroke Subjects

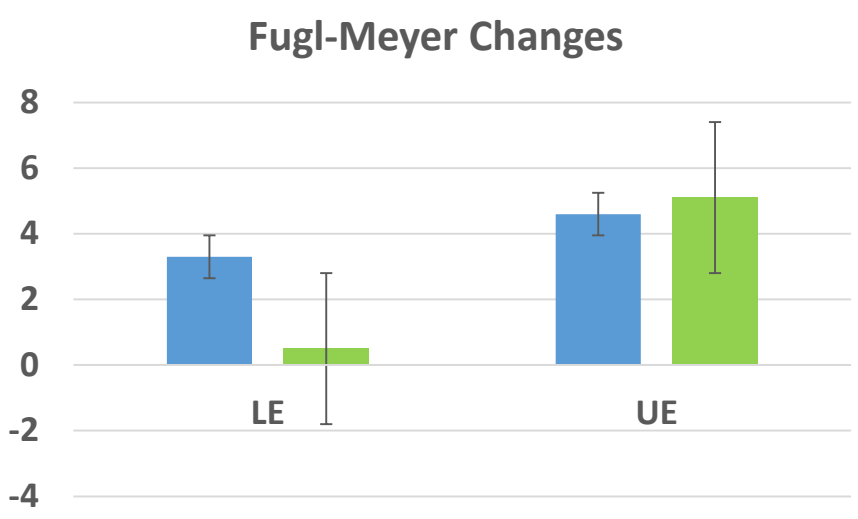
- Ischemic stroke; hemiplegia >6months post stroke
- No more than mildly cognitively impaired
- Various levels of function
- Control Group (CG) v. Robot Group (RG)

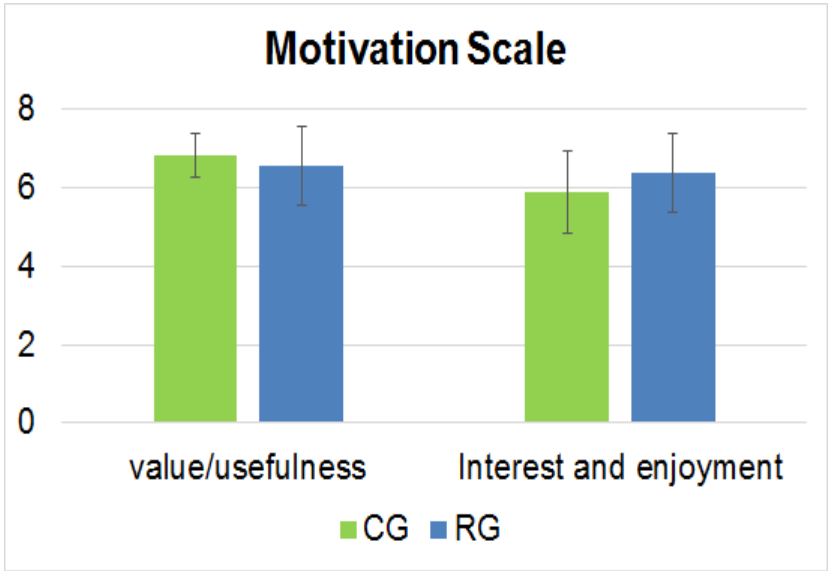


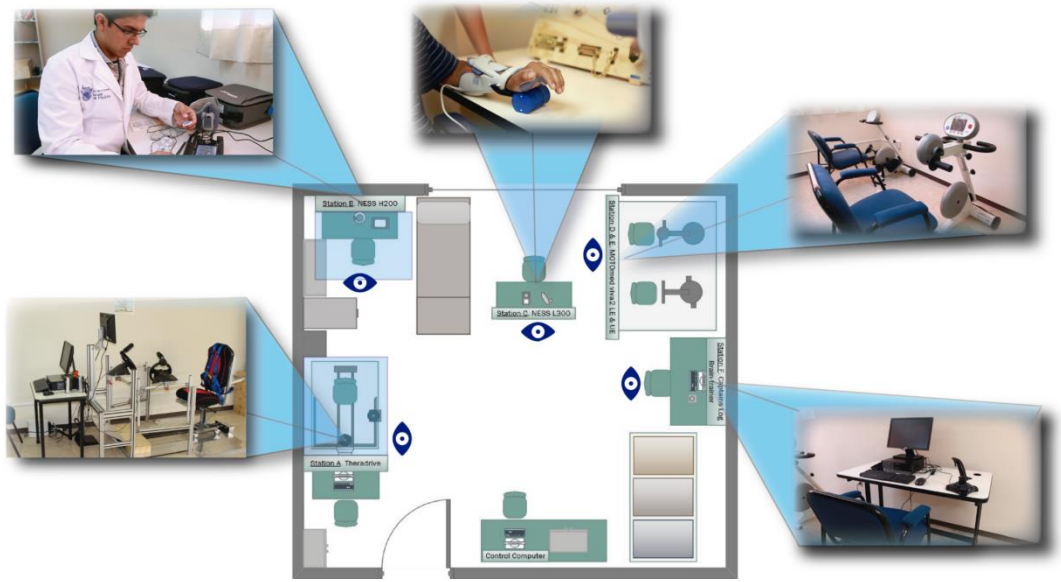
Results

- Changes in UL Motor Impairment and Function
  - FM: RG: 4.6±3.89; CG: 5.1±4.72: p=0.79
  - BBT: RG: 2.2±3.61; CG: -0.3±3.30: p=0.13
- Changes in LL Motor Impairment and Function
  - FM: RG: 3.3±3.59; CG: 0.5±1.71 (p=0.035)
  - 6MMW: RG: 13.5±35.96; CG: 18.1±15.80: p=0.26
- Intrinsic Motivation
  - valuable (RG: 6.83±0.56 and CG: 6.57±1.04: p=0.14)
  - engaging (RG: 6.36±1.23 and CG: 5.89±1.6: p=0.27)
- Labor >> 1:1112 ($19.21)to 1:6672 ($4.29)

$$Therapy\ Cost/Session = \frac{Equipment\ and\ Mainteinance\ Costs + Therapist's\ Annual\ Salary}{\#\ of\ patients\ treated\ in\ a\ year}$$






Station B NESS H200
Station C NESS L300
Station A Theradrive
Control Computer


AFFORDABLE
EFFECTIVE
ACCESSIBLE

Rehab

C.A.R.E.S.

Gym

Rehab CARES is a portable compact system designed to support the upper and lower extremity and facilitate gait and balance training.

Special Collection: Affordable Rehabilitation and Assistive Technologies

RATE

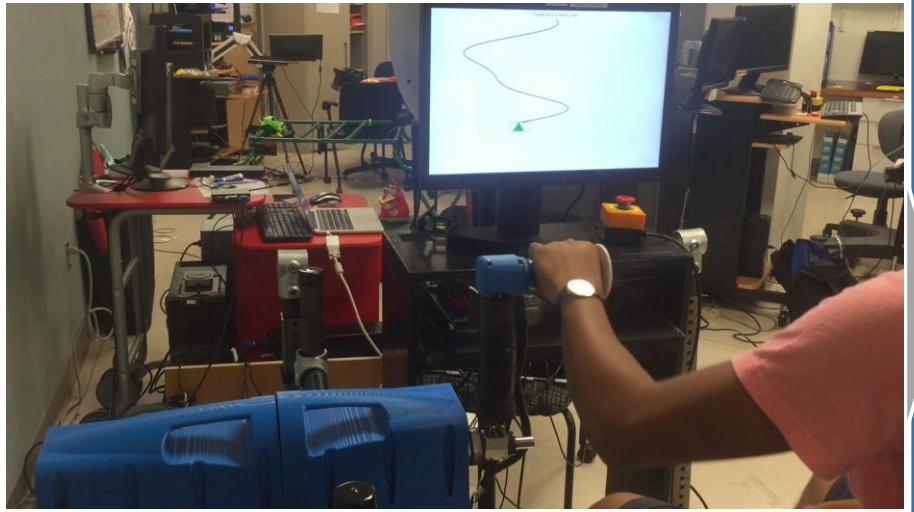
Journal of Rehabilitation and Assistive Technologies Engineering
Volume 4: 1–12

DOI: 10.1177/2055668317708732
journals.sagepub.com/home/jrt

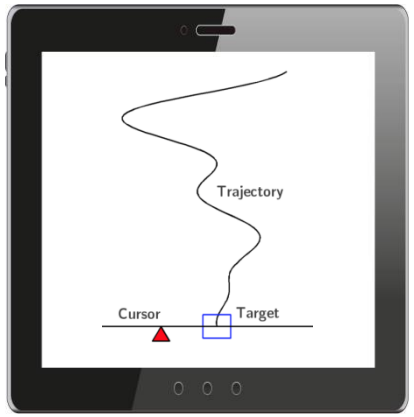
Affordable stroke therapy in high-, low- and middle-income countries: From Theradrive to Rehab CARES, a compact robot gym

Michelle Jillian Johnson[1,2,3], Roshan Rai[1,3], Sarath Barathi[3], Rochelle Mendonca[4] and Karla Bustamante-Valles[5,6]

Hardware (Active or passive)



Task (Diagnosis or Therapy)



Data Collection

Diagnosis
- RMS error
- Rate of learning
- Force

Therapy
- RMS error
- Force
- Required assistance or resistance
- Game parameters - scores, levels cleared etc.

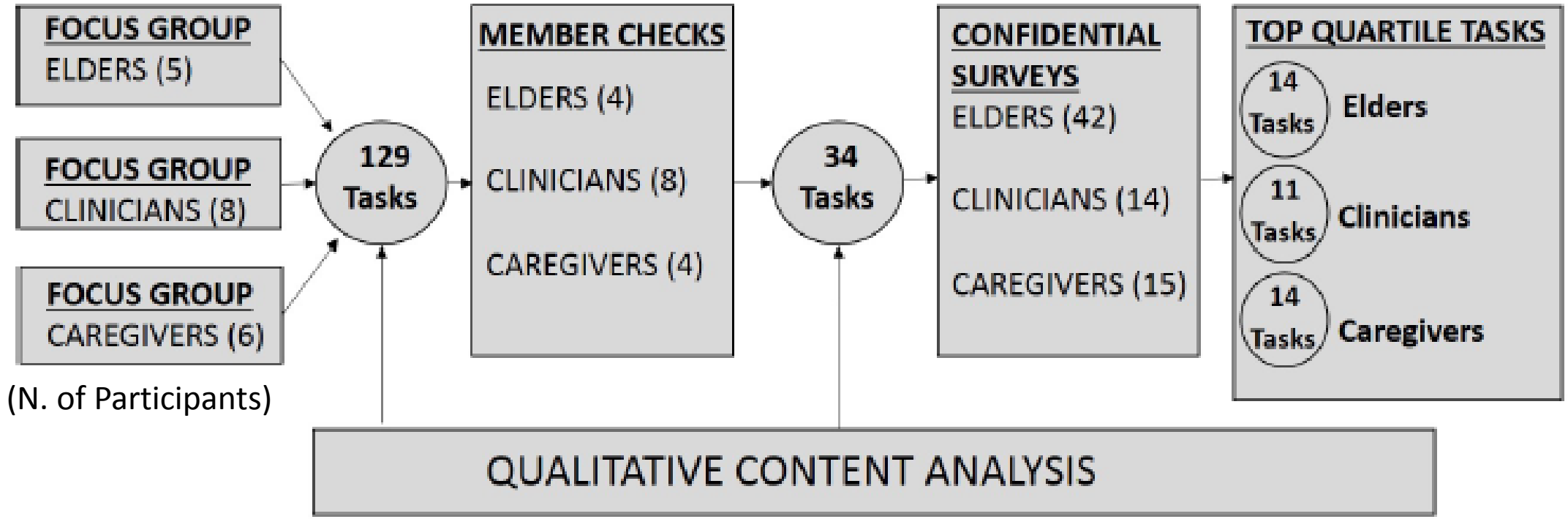
Overall
- Total number of subjects
- Data analytics on aggregated data

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.

Autonomy

- Older persons desire independence and inclusion
- Robots MUST help with prevention care to assist in maintaining autonomy
- Robots and Technology MUST balance autonomy with efficiency to protect patients data, privacy, security, and well being.

Case-Study: Affordable Service Robots (Day Care)



* 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.

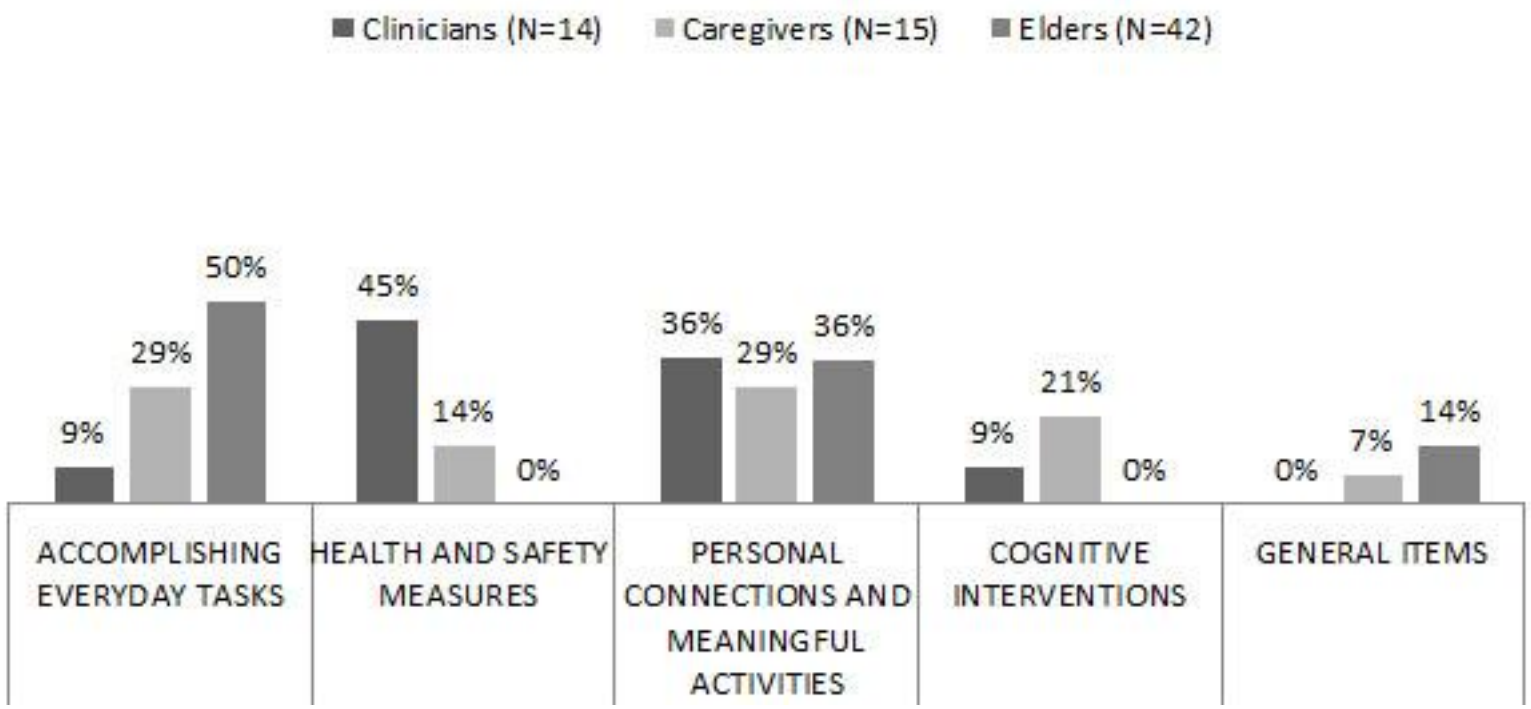
Elder Care: Low-Cost Assistive Mobile Robot

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]



Elder Prioritize List

- Themes
  - Hydration
  - Social Connection
  - Manipulation
  - Monitoring

Int J of Soc Robotics
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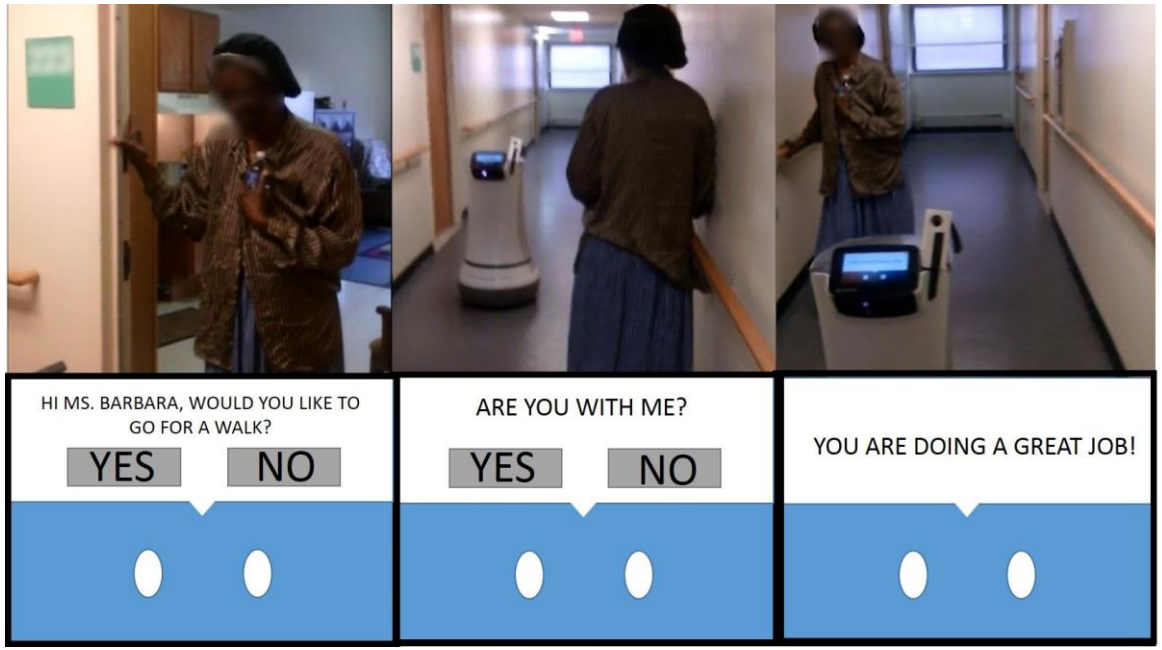
	Rank
Having additional assistance when pain flares up	1
Outings (shopping, supermarket)	2
Having your food preference known	3
Getting a drink	4
Being asked about your preference	5
Assistance with being in bed (change position, putting on blanket)	6
Having caretakers help keep spirits up	7
Reaching things 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

Mobile only Deployments*

Autonomous Hydration reminder and Water delivery



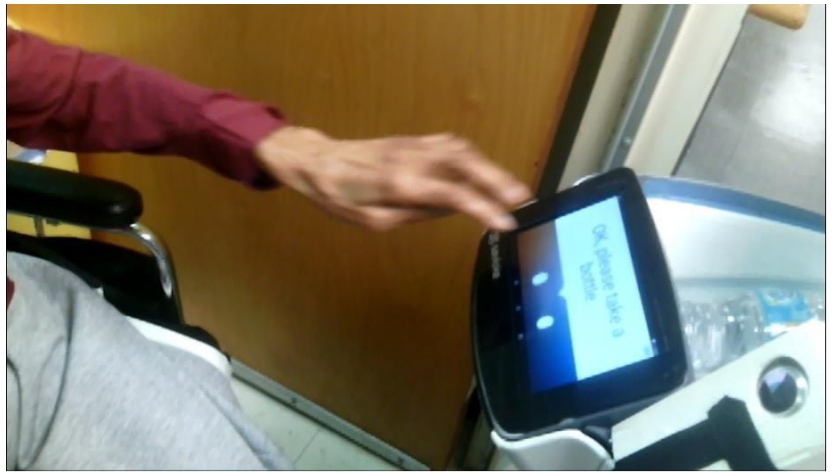
Walking encouragement

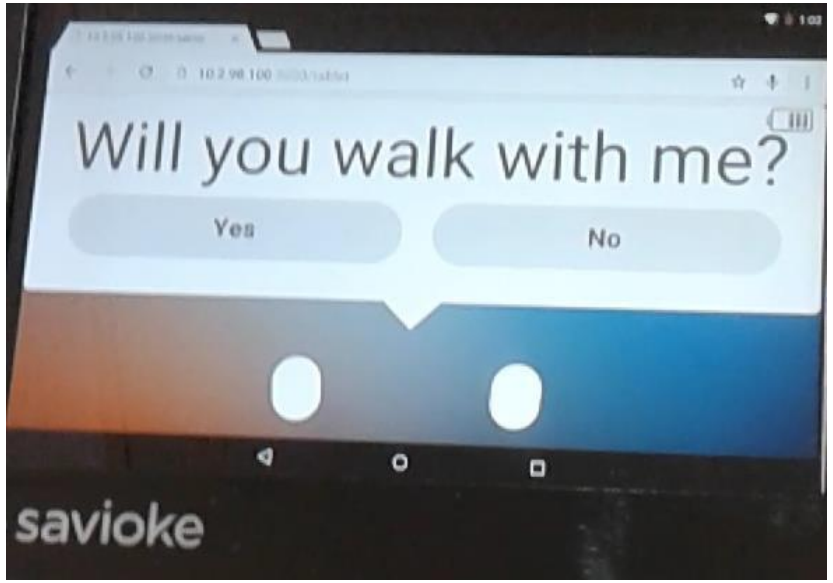
***Mucchiani C, Sharma S, Johnson M, Sefcik J, Vivio N, Huang J, Cacchione P, Johnson M, Rai R, Canoso A, Lau T.** 'Evaluating older adults interaction with a mobile assistive robot' In IEEE/RSJ International Conference on Intelligent Robots and Systems, **IROS 2017**.

Design guidelines for Mobile Service Robots Interacting with Elders

Penn Engineering | GRASP Laboratory
General Robotics, Automation, Sensing & Perception Lab

Observation	Design Guideline
Tendency to read (not listen) instructions	Larger fonts
Difficulty with touchscreen	Larger or physical button
Ask to repeat	Repeat function
Verbally say “YES” or “NO”	Voice recognition
Low Volume	Loud Speakers
Difficulty reaching bin	Open to side (not top)
Confuse robot eyes with buttons	Better UI or physical buttons



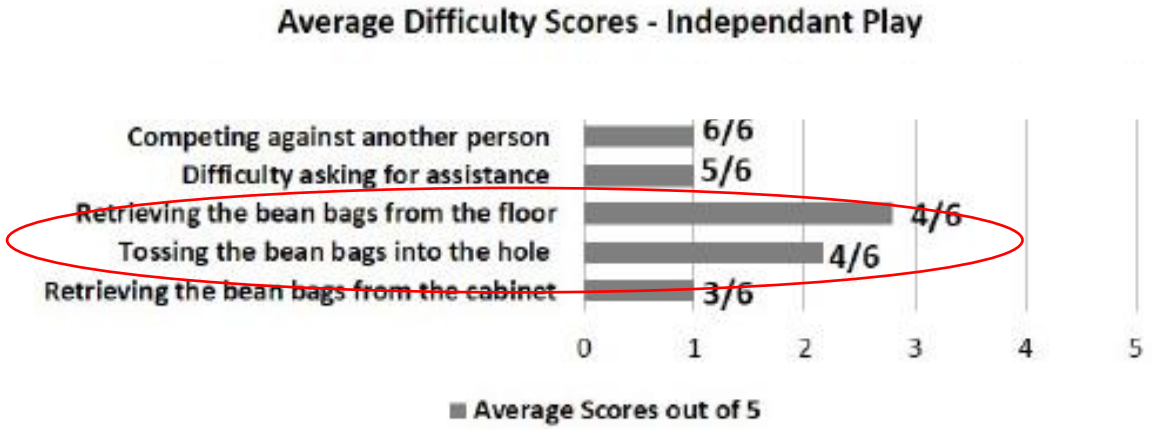


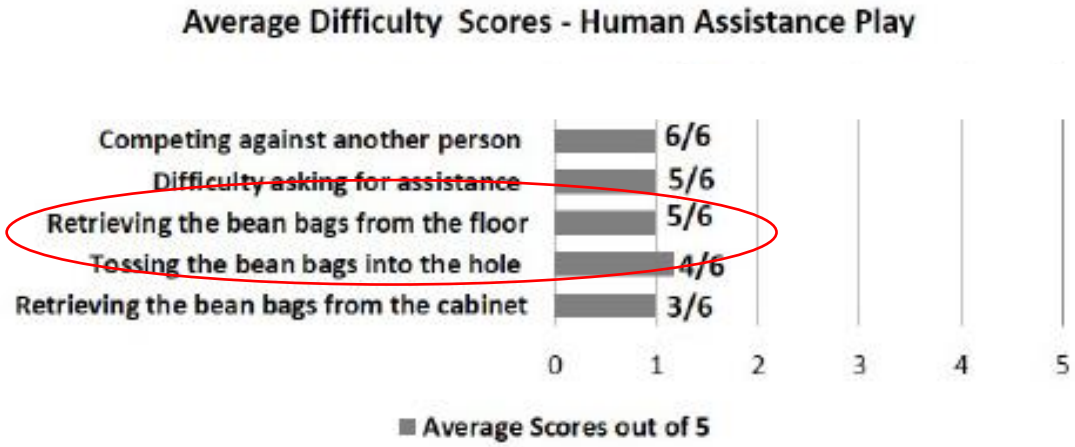
Mobile and Arm Deployment

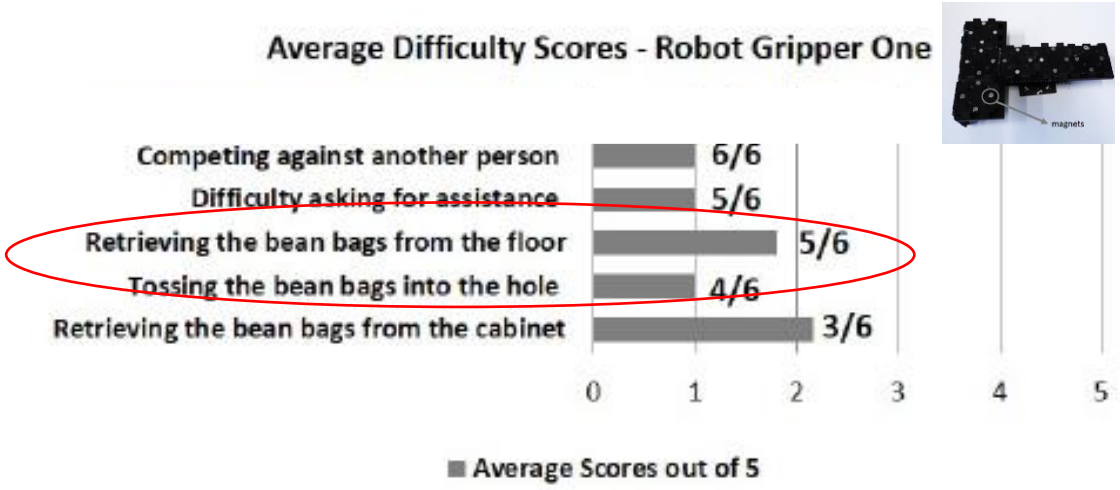


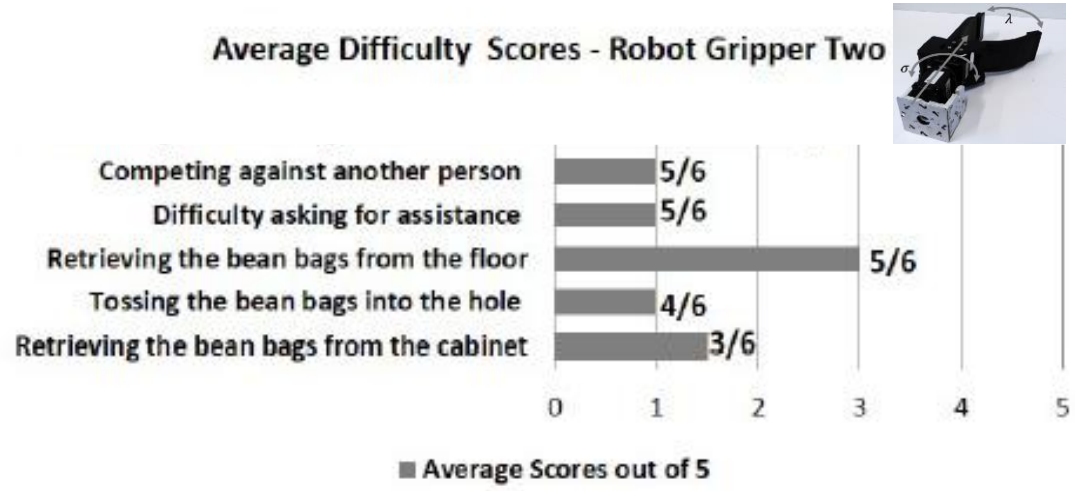
Results: Elders self reported scores

Average difficulty scores



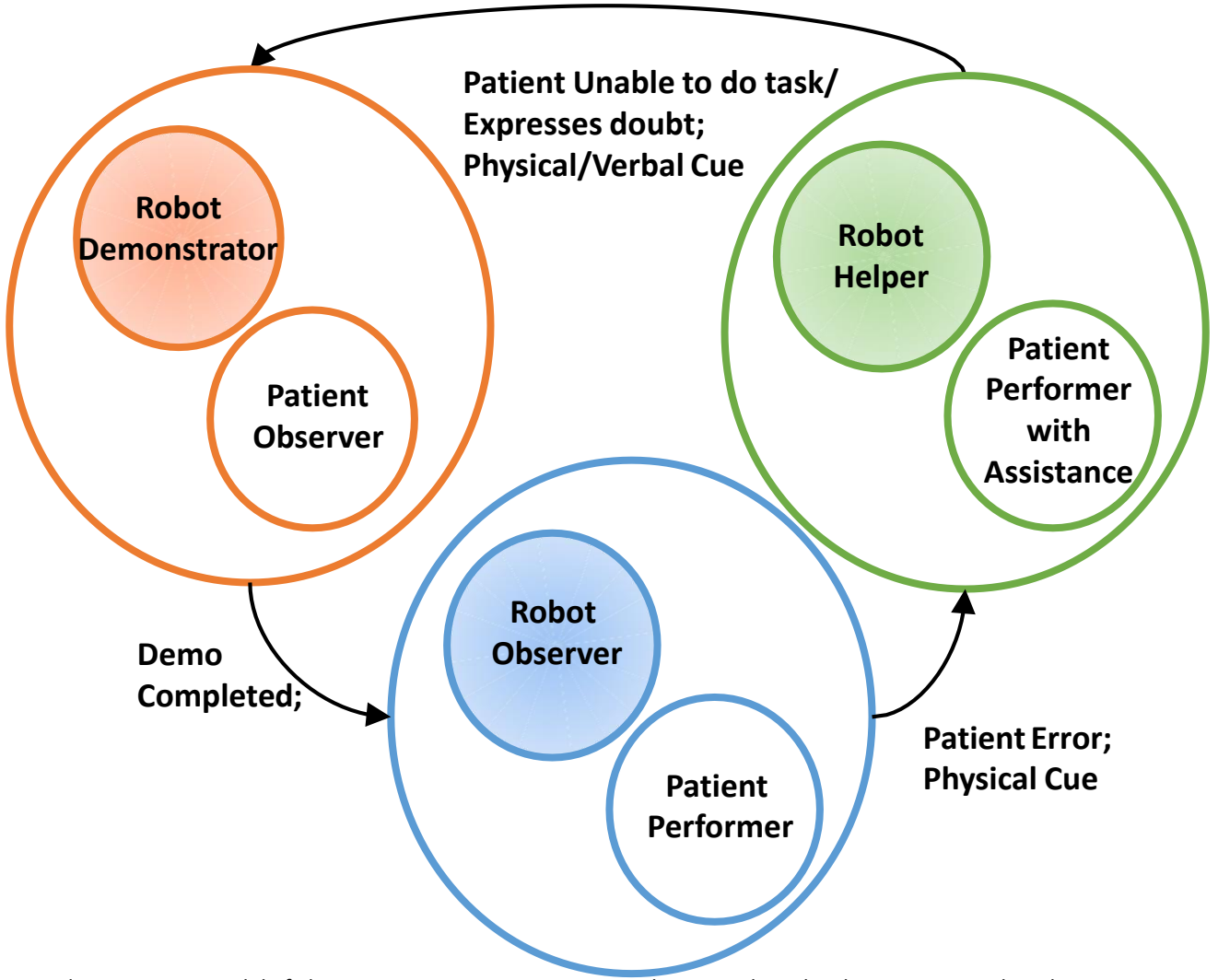






Post-interaction surveys with elders: high acceptance of the robot as an assistant in the game

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*

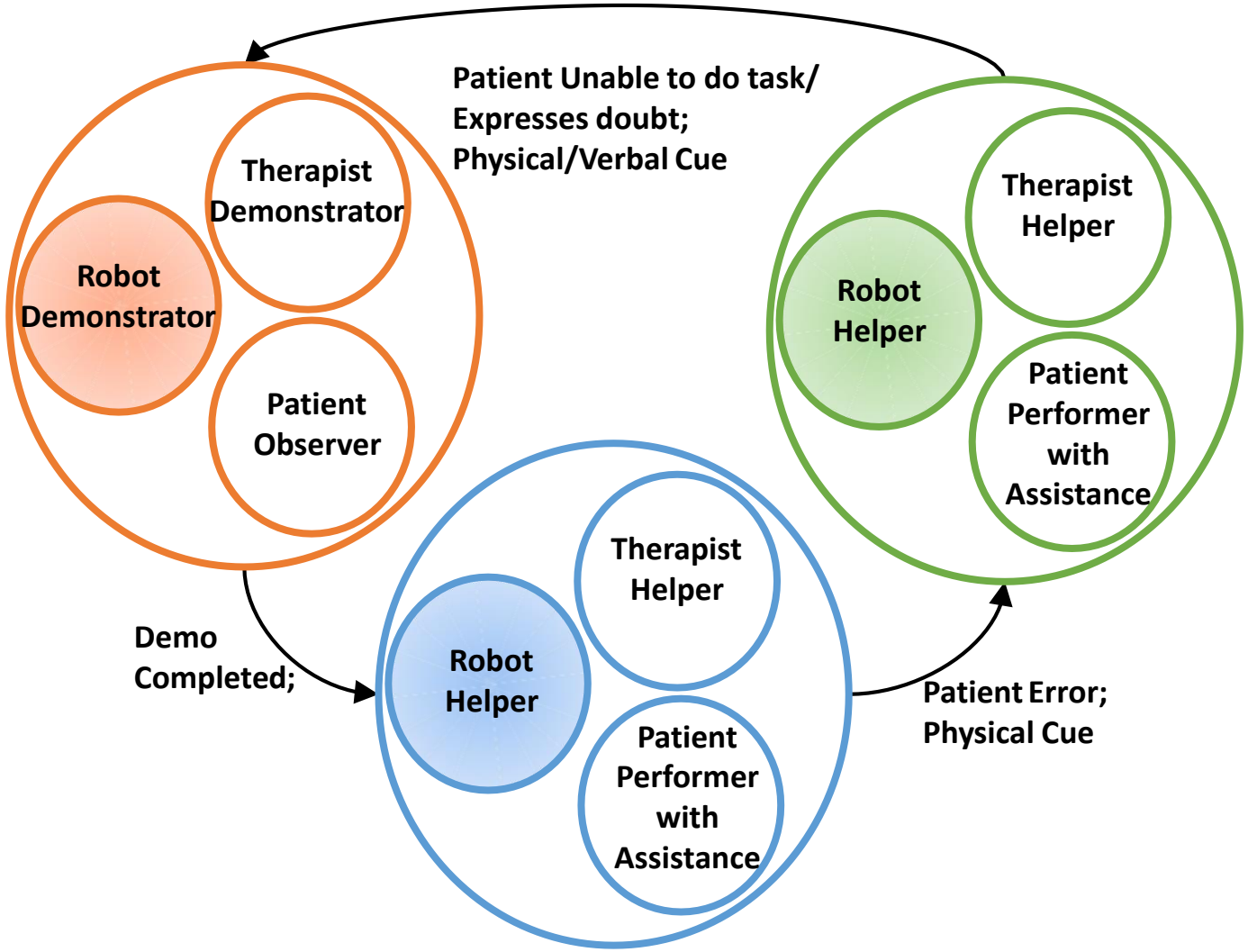
Autonomous Robot Guidelines

- 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
- Protect patients data, privacy, security, and well being.

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 may not be VERY safe
- Robot may not be as good as clinician/therapist
- Robot may not be able to easily obey privacy and security rules
- Robot implementation may not be covered by laws and using them may not be covered in healthcare system

Scenario 2: Shared Control with Therapist



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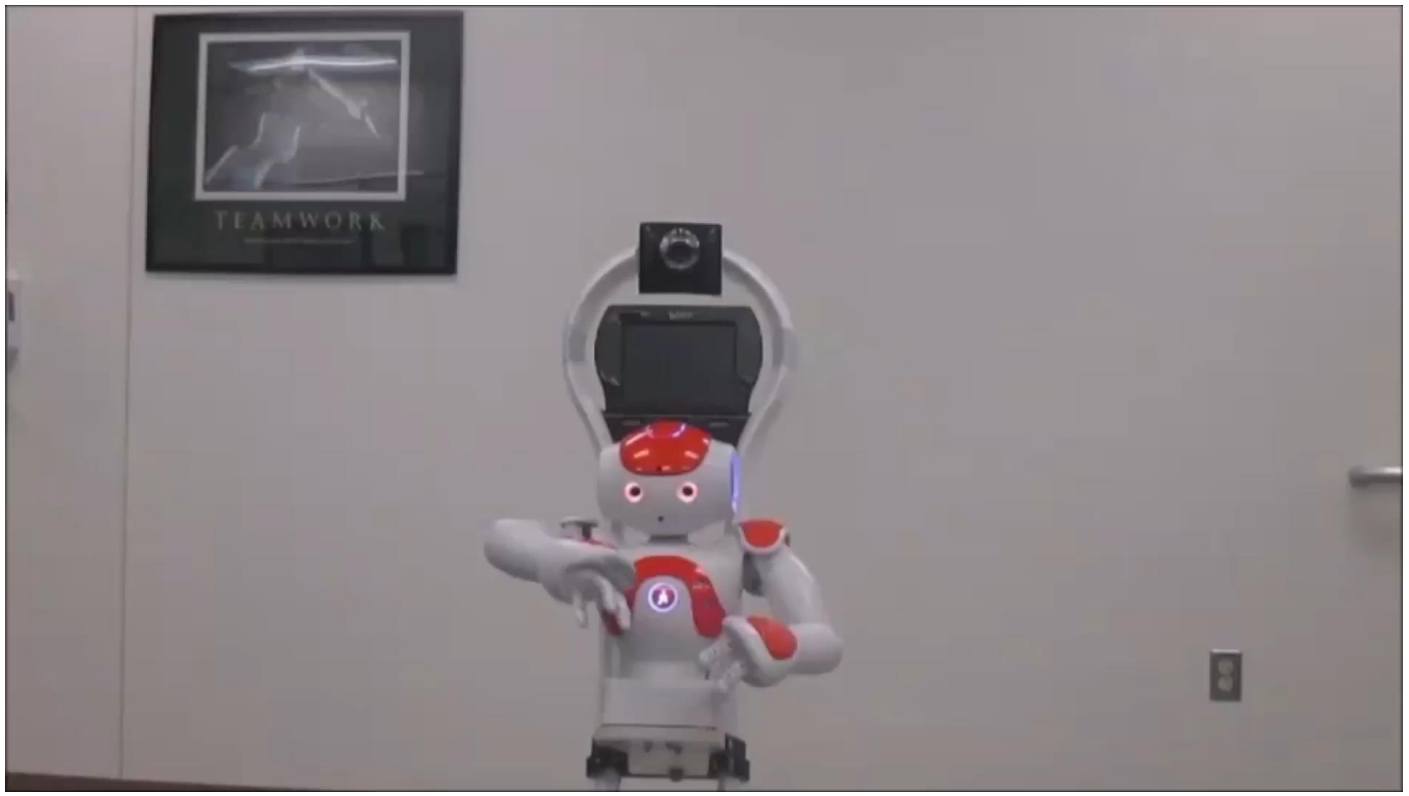
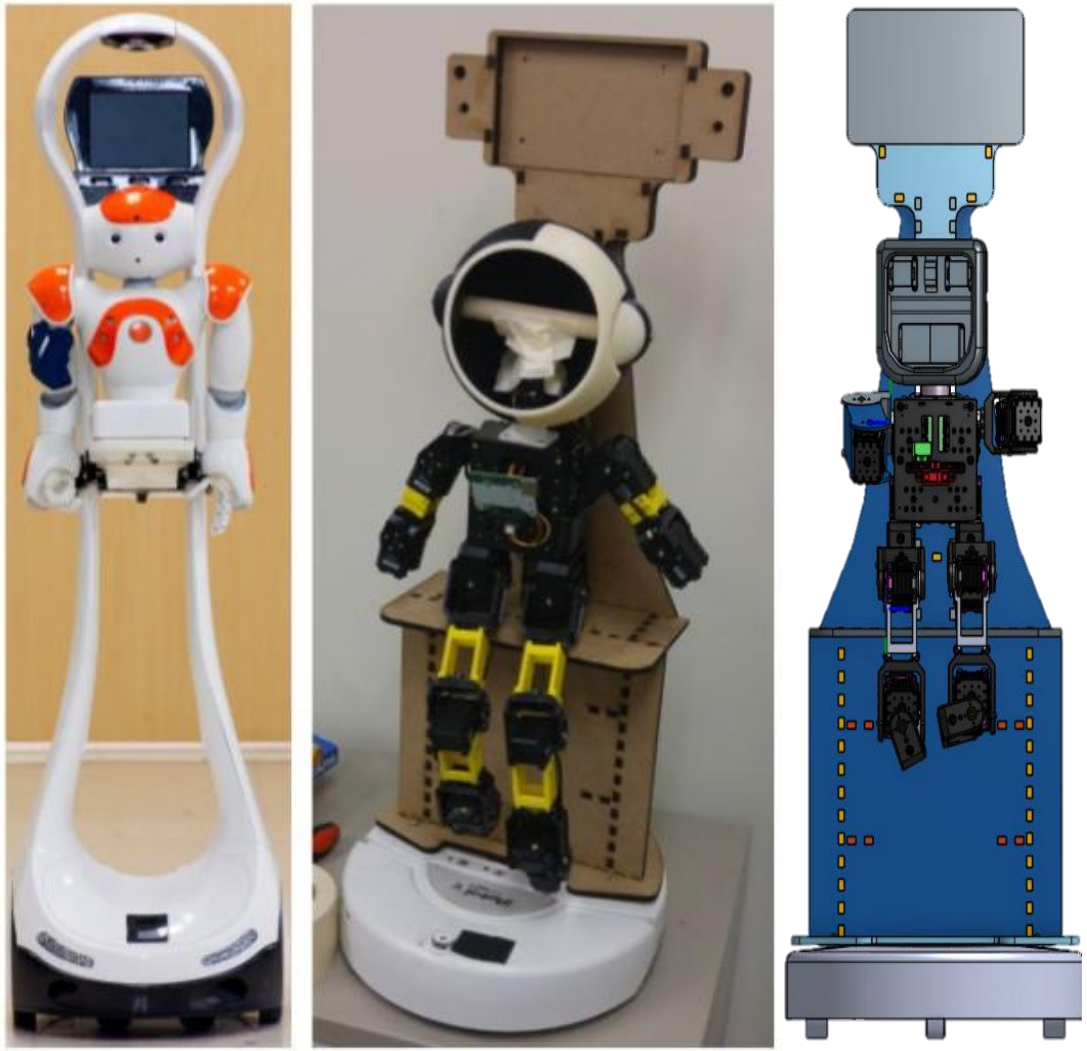
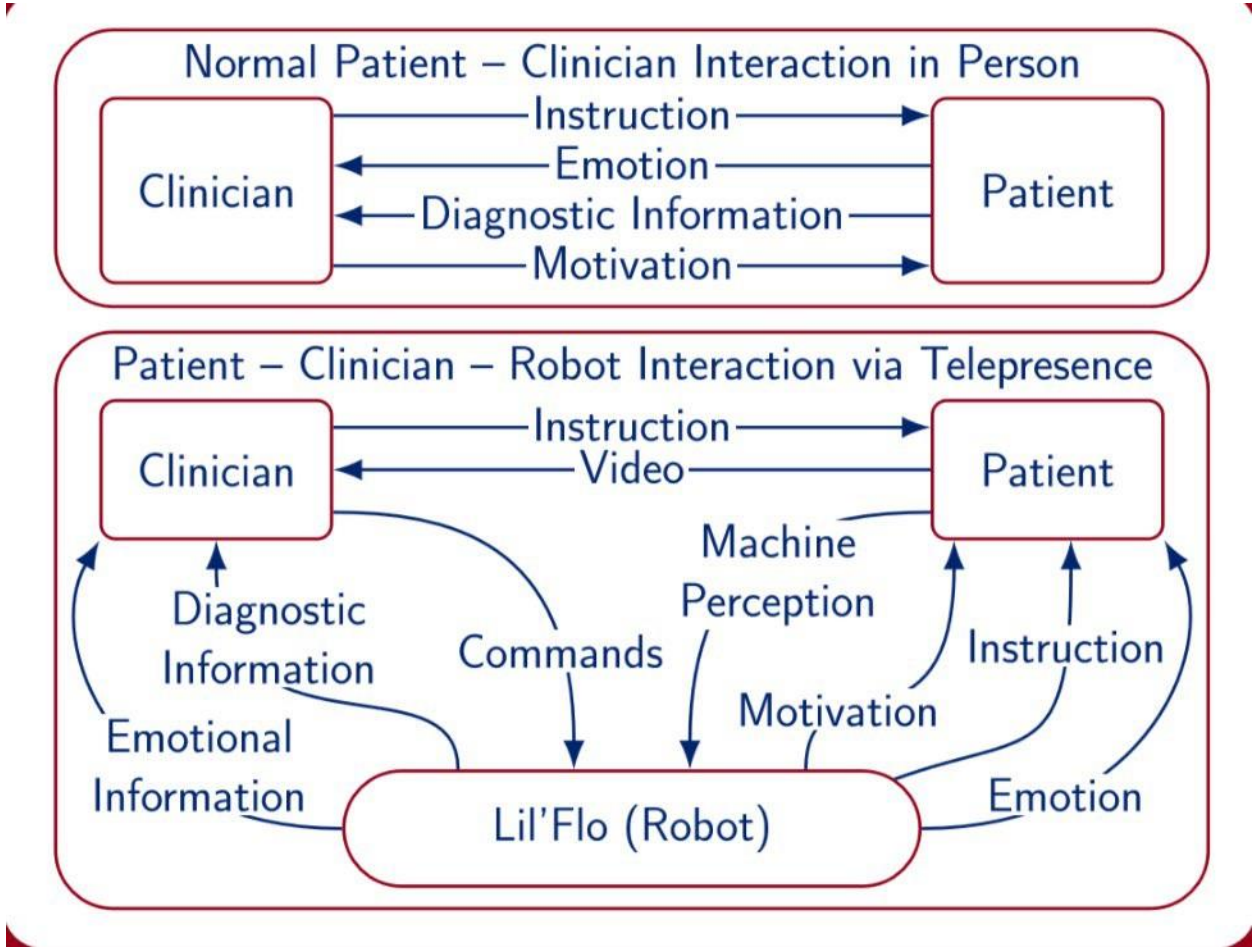
Flo: Mobile Therapist



Affordable Socially Assistive Robot for Local and Remote Diagnostics of Upper Limb

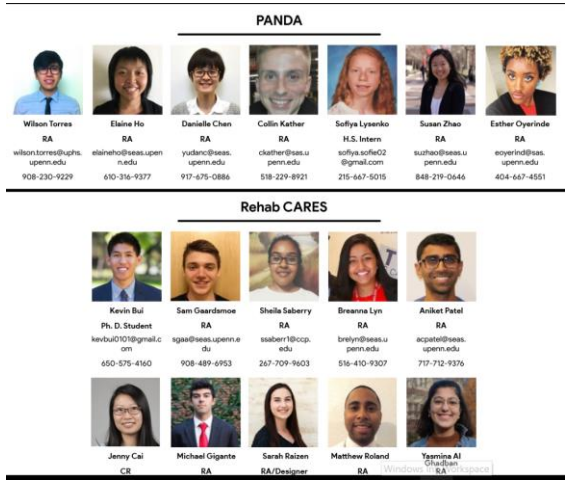


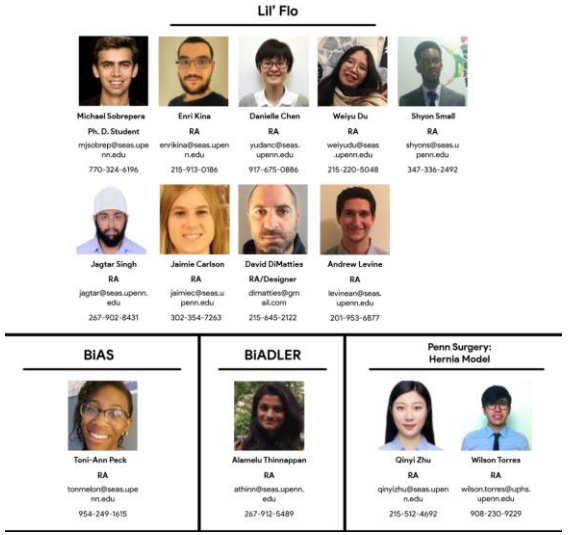
Sobrepera M, Johnson MJ: Design of Lil Flo an Affordable Socially Assistive Robot for Telepresence Rehabilitation. RESNA 2018, Washington, DC.



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)





Lab Team (Past and Present)

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- Council of Elders at the PACE and SAL staff and members at LIFE center
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- 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

Penn Nursing Science

NSF

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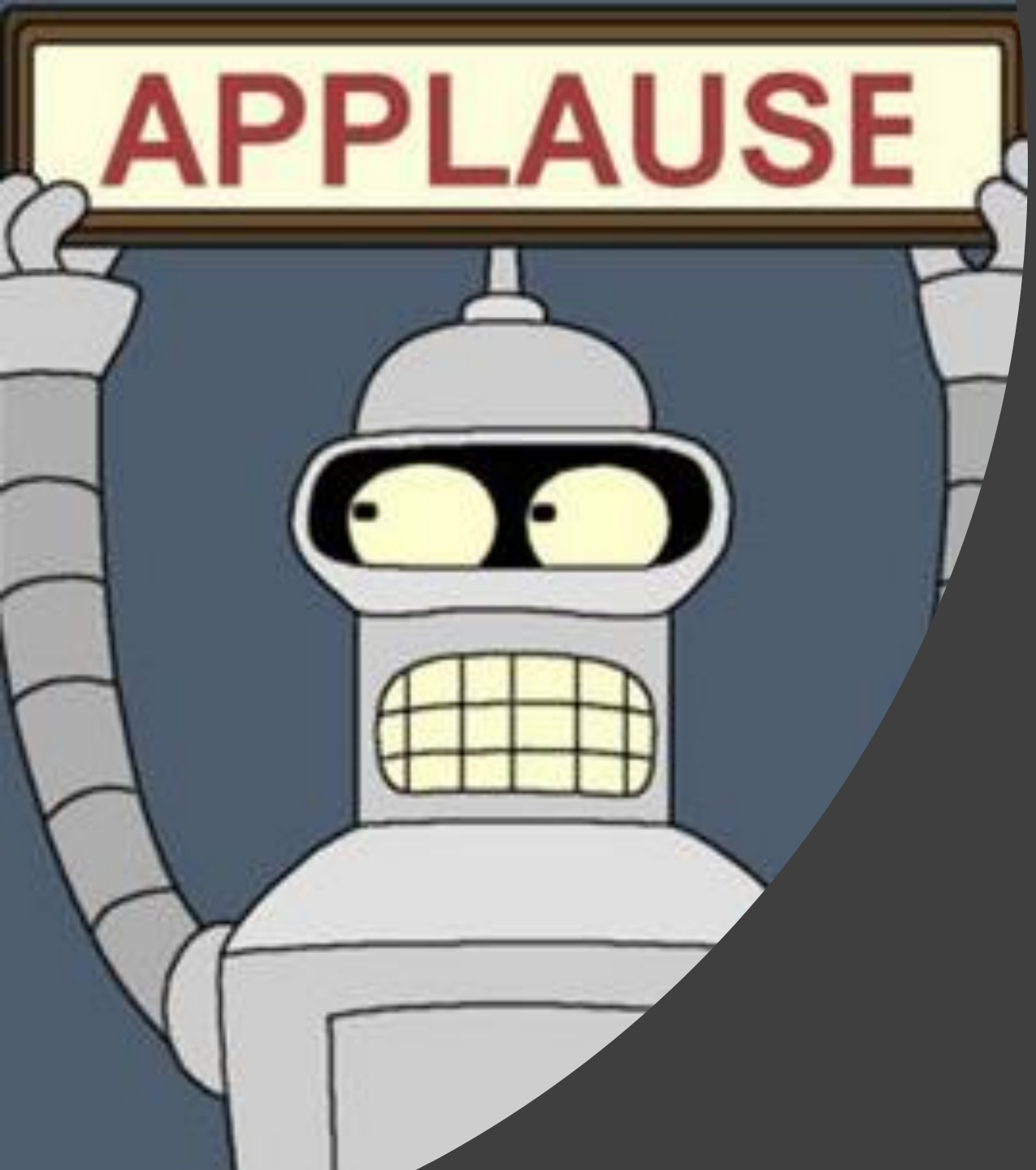

QUESTIONS?