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

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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

Myomo Pro
Baxter: Elder Exercise

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

Mabu: Chronic Disease Management

Mabu: A Personal Healthcare Companion

• 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/healthcare 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
## What is Affordable*?

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

* USE WHO Cost-Effective Thresholds

**HIGHERLY COST-EFFECTIVE = < A**

**A > COST-EFFECTIVE < B**

**UNREASONABLE >B**
Case-Study: Affordable Therapy Robot Gym

- Rehabilitation Robotics Lab (MCW/MU/UPENN)
- ITESM Campus Chihuahua, Chihuahua, Mexico
- CREE: Centro de Rehabilitacion y Educacion Especial DIF NL, Chihuahua, Mexico
20 Stroke Subjects

- Ischemic stroke; hemiplegia >6 months 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 = 
\[ \text{Equipment and Maintenance Costs} + \text{Therapist's Annual Salary} \]
\[ \div \text{# of patients treated in a year} \]
Rehab CARES is a portable compact system designed to support the upper and lower extremity and facilitate gait and balance training.
Diagnosis
• RMS error
• Rate of learning
• Force
• RMS error
• Force
• Required assistance or resistance
• Game parameters - scores, levels cleared etc.

Therapy
• Total number of subjects
• Data analytics on aggregated data

Overall

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)
Elder Care: Low-Cost Assistive Mobile Robot

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

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### Elder Prioritize List

- **Themes**
  - Hydration
  - Social Connection
  - Manipulation
  - Monitoring

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

Autonomous Hydration reminder and Water delivery

Walking encouragement

# Design guidelines for Mobile Service Robots Interacting with Elders

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

- **Robot Demonstrator**
  - Patient Unable to do task/Expresses doubt; Physical/Verbal Cue

- **Robot Helper**
  - Patient Performer with Assistance

- **Patient Observer**
  - Demo Completed;

- **Robot Observer**
  - Patient Error; Physical Cue

- **Patient Performer**

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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

Flo: Mobile Therapist
Affordable Socially Assistive Robot for Local and Remote Diagnostics of Upper Limb

Integrated Systems Health Management

- Fault detection (detecting that something is wrong)
- Fault isolation (determining the location of the fault)
- Fault Diagnostics (isolation & identification)
- 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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QUESTIONS?