Quality of Life Technology Center
a National Science Foundation Engineering Research Center

Emerging Technologies for Aging and Disability

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University of Heidelberg, Oct. 9, 2013

Carnegie Mellon University of Pittsburgh

Overview

1. QoLT Philosophy & Overview
2. Core Technologies & Systems under Development
3. Privacy, System Demand, and Cost Issues

I. QoLT Philosophy & Overview

Quality of life Technology Engineering Research Center

Creating intelligent systems that enable older adults and people with disabilities to live independently

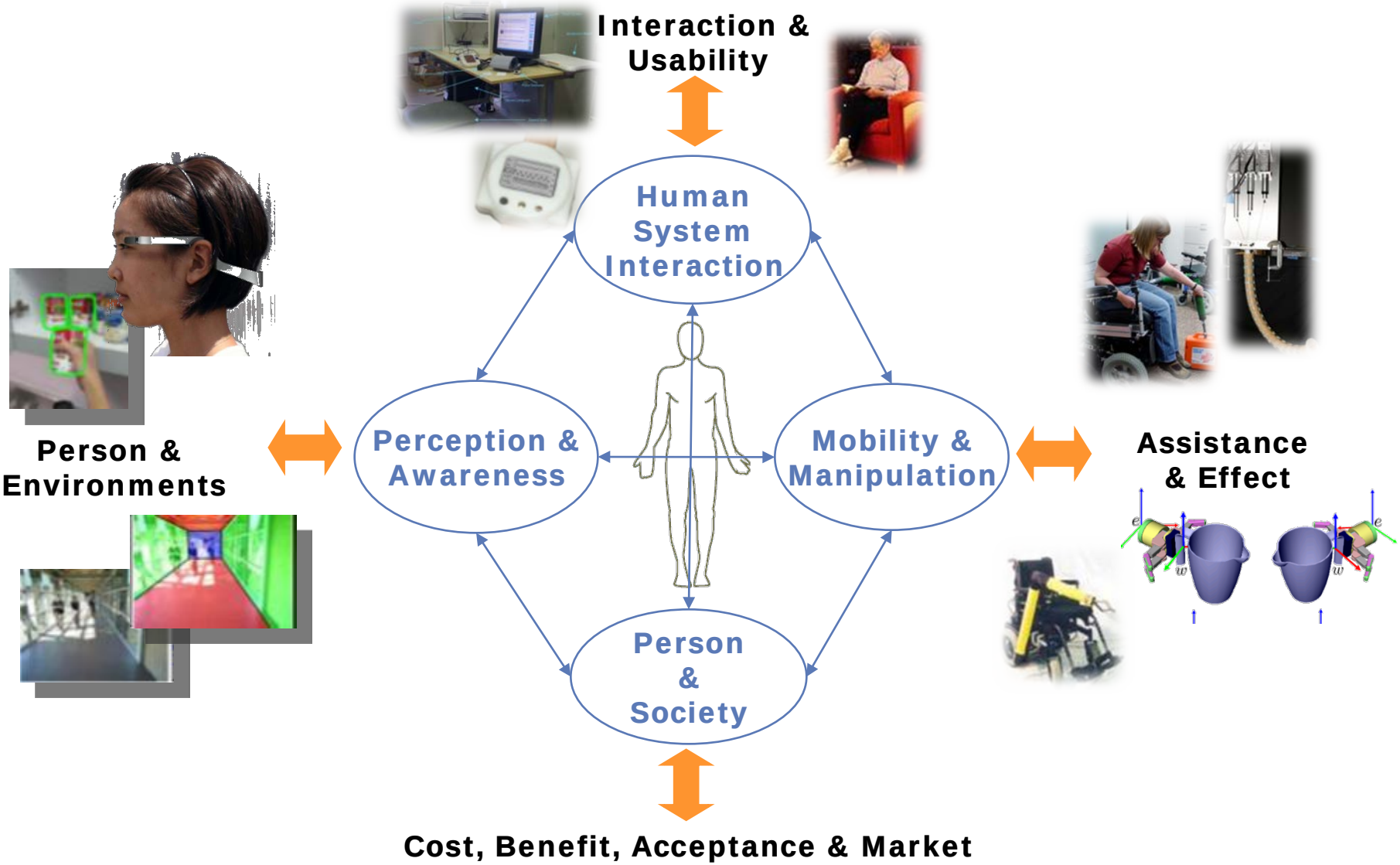
From "*autonomous*" to *"symbiotic"* systems with balanced involvement of person and technology

- Person-System Symbiosis
- Person-Aware and Environment-Aware

New technologies:

- Robust perception of the person and unstructured environment
- Soft, safe manipulation of person and everyday objects
- Dynamic and adaptive interaction

QoLT Core Research Thrusts



QoLT Testbed Systems

QoLTbots

Provide reactive and proactive manipulation assistance for activities of daily living.

Virtual Coach

Provide cognitive and memory assistance and enhanced motivation in contexts ranging from exercise to daily tasks.

Safe Driving

Provide ways to make driving safer for older adults and people with disabilities.

Home & Community Health and Wellness

Combine person and task awareness to support healthy independent living.

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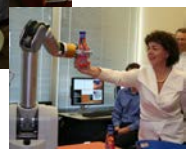
Proving Ground

Home & Community Health & Wellness



QoLTbots

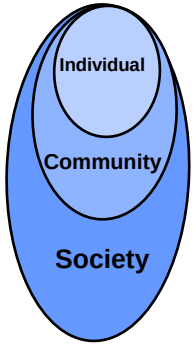
Safe Driving

Virtual Coach

Testbed Systems

Needs & Feedback

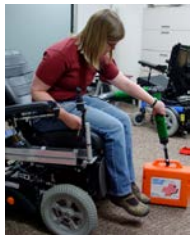
Products



Requirements

Technologies & Insights

Basic Research



Mobility & Manipulation

Perception & Awareness

Person & Society

Human-System Interaction

Industry/Practitioner Collaboration & Spin-off Company Creation

Allstate, Bluerooof, intel, Panasonic, BOSCH, ETRI, Presbyterian SeniorCare, etovia, NavPrescience, SAMSUNG, GM, Honeywell, NISSAN, VibeAttire, first person vision, Tiramisu

Education, Outreach & Diversity Enhancement

QoLT Systems: Functionalities and Target Populations

	Sample systems	Key Functionalities	Targeted Populations (size)	Target Industry
Virtual Coach *Memory & reasoning support wherever a person goes and whatever he or she does*	Navigation for public buildings	retrieve signage information	people with visual impairments (>3M)	Retail, Electronic medical record, Infotech, Exercise equipment, Healthcare equipment, Assistive living, Nursing institution
	Medical device usage coach	provide appropriate guidance, feedback and reinforcement communicate with clinicians	people with Mild Cognitive Impairment (>6M)	
	Personal rehab coach	recognize correct movements track performance	survivors of stroke (3M)	
Home / Community Health and Wellness *Perceptive environments support a person's physical, mental and emotional state*	Cognitive Kitchen	recognize kitchen activities provide cues for actions	people with TBI (5.3M) people with MCI (>6M)	Appliance, Home security, Consumer electronics
	Health Kiosk	measure and record vital signs allow interaction with clinicians	older adults living alone (4M)	
QoLTbots *Personal robots that assist with ADLs and IADLs*	Personal Mobility & Manipulation Appliance	manipulate objects on behalf of the user	wheelchair users with dexterity impairment (0.2M)	Assistive technology
		assist with transfers between chairs, beds, toilets, etc.	all wheelchair users (4M)	
	Home Exploring Robot Butler	retrieve and place objects prepare meals do household chores	people with mobility impairments (10M) frail elderly (4M)	
Safe Driving *Ways to make driving safer for older adults and people with disabilities*	DriveCap	continually assess a person's capability to drive a vehicle	drivers with vision (>3M) or hearing impairments (24M) people with Mild Cognitive Impairment (>6M)	Automotive industries, Infotech
	DriveCap Navigator	provide route instructions tailored to user's driving capability and prevailing road/environmental conditions		

Product Development and Evaluation Timeline

User Needs and Task Analysis

User-centered Design Prototype → Robust Prototype → Laboratory Prototype → Field-deployed System → Commercially-viable Application → Commercial Product

Evaluation Design Strategies

L A B

User-centered design methods (Iterative)
Prototyping design and testing
Observation of task performance w/technology
Laboratory testing
Storyboarding
Rich stimulus displays
Scenario testing
"Wizard of Oz" studies
Individual in-depth interviews / "think aloud"
Focus groups/ Group-individual synthesis

F I E L D

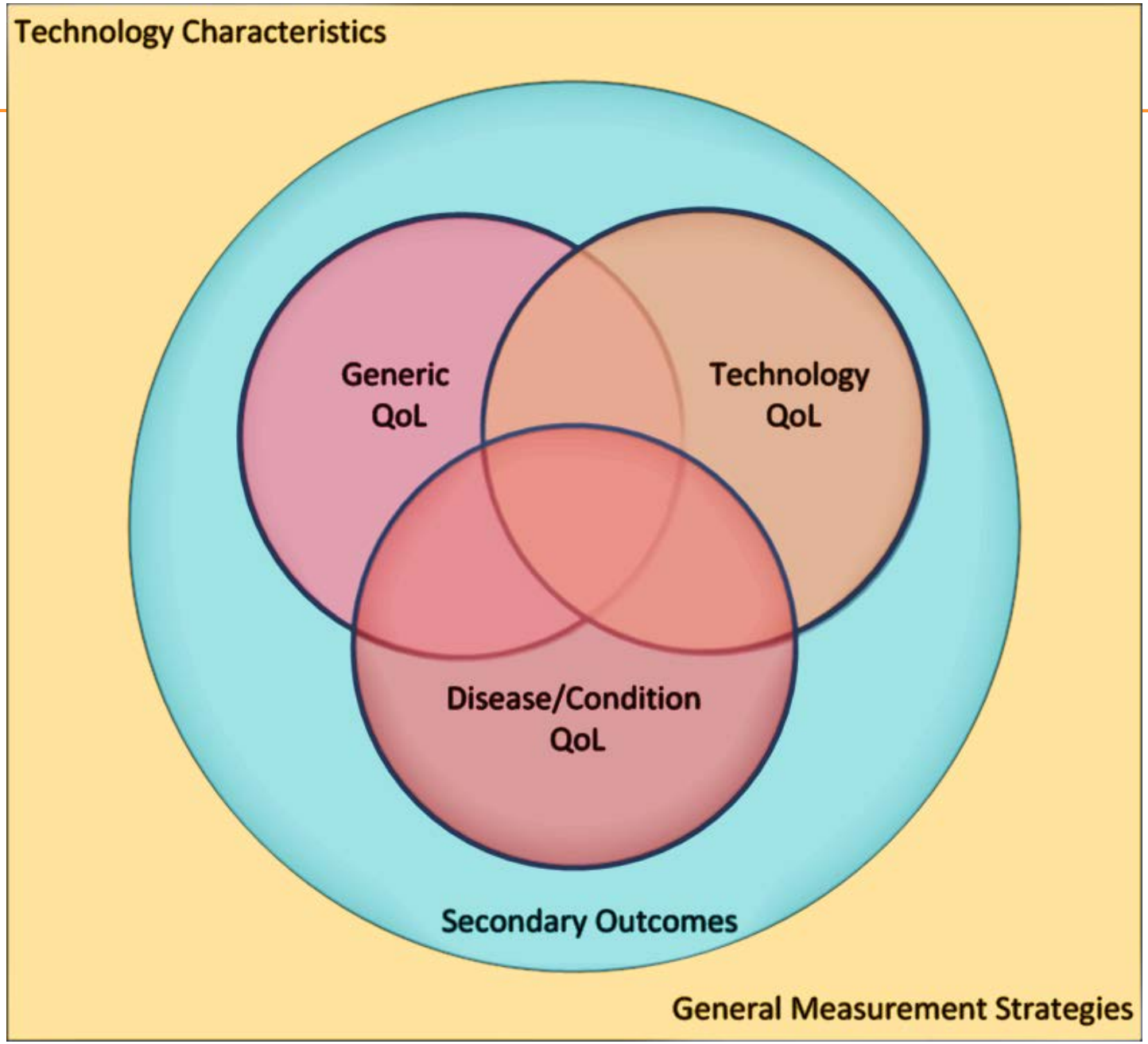
Field testing
Pilot trial
Randomized efficacy trial
Effectiveness trial
Comparative effectiveness trial
Acceptance and adoption study

Measurement Strategies

Ease of use; Acceptability; Reliability; Learnability; Effectiveness; Efficiency; Errors; Flexibility; Memorability; User satisfaction; Safety; Confidence; Aesthetics; Convenience; Intrusiveness / privacy concerns

Adoption / uptake
Real-world task performance
Quality of Life
- *Technology-specific*
- *Disease/condition specific*
- *Generic*

Secondary / broad outcomes
- *Need for formal/informal caregivers*
- *Caregiver burden*
- *Healthcare costs*
- *Value to healthcare providers*


Technology Characteristics
Generic QoL
Technology QoL
Disease/Condition QoL
Secondary Outcomes
General Measurement Strategies

II. Core Technologies and Applications

Core Technologies

- Perception and Awareness--Seeing and understanding the environment, inferring intent
- Mobility and Manipulation—moving, reaching, grasping, pushing, pulling, holding
- Human-system interaction--Interfacing with humans
- Individual and societal factors shaping acceptance and adoption

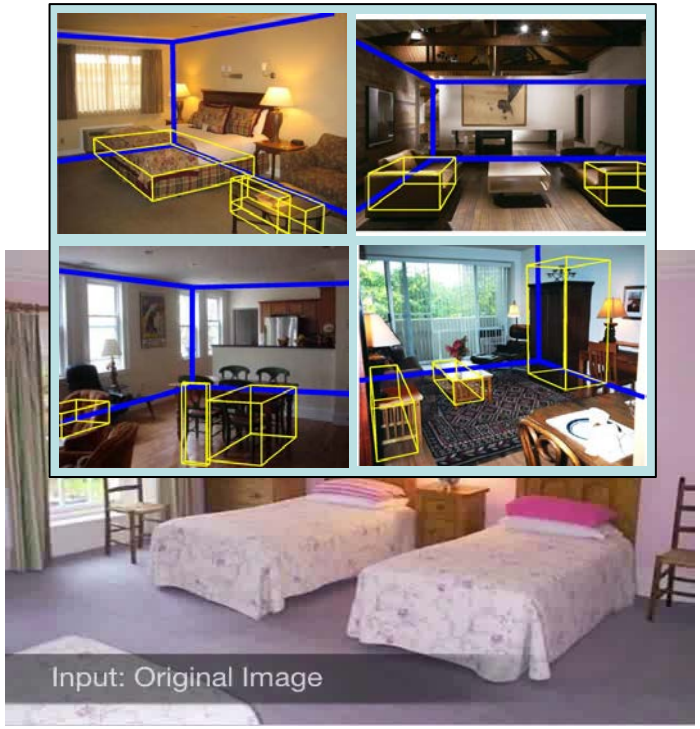
Everyday Life Scene Recognition

Lowering the *Complex Interactions and Contextual Variability* barrier

In addition to recognize a *given* object, QoLT systems must discover in the first place *what* objects are there, and understand how they relate to the user

- see partially occluded objects
- identify objects in cluttered env.

Discover objects that a person uses



Face Recognition

Cooperative Manipulation

Soft Robot—cooperative manipulation

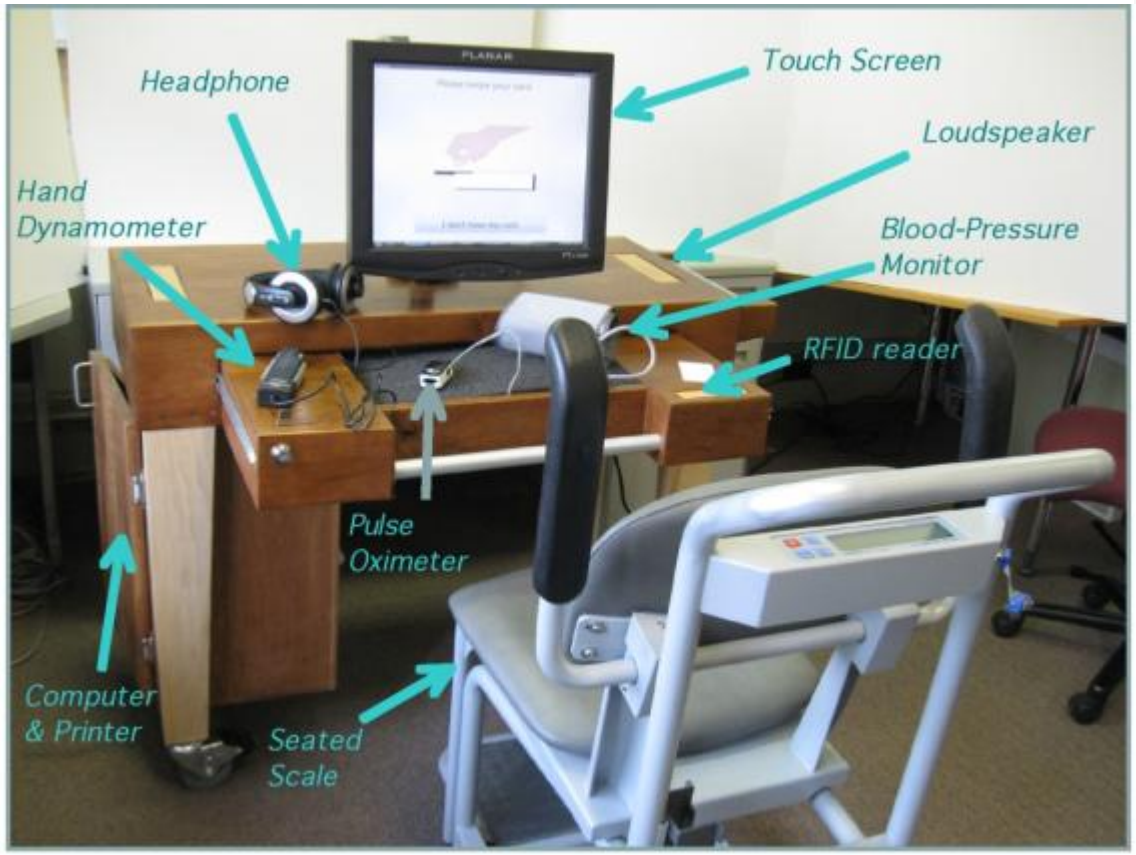
HERB—Push Grab

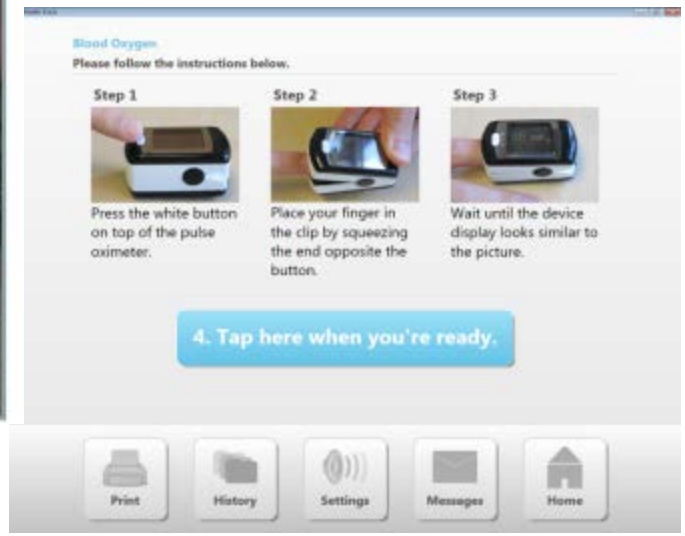
HERB

HERB—Delicate Manipulation (Oreo)

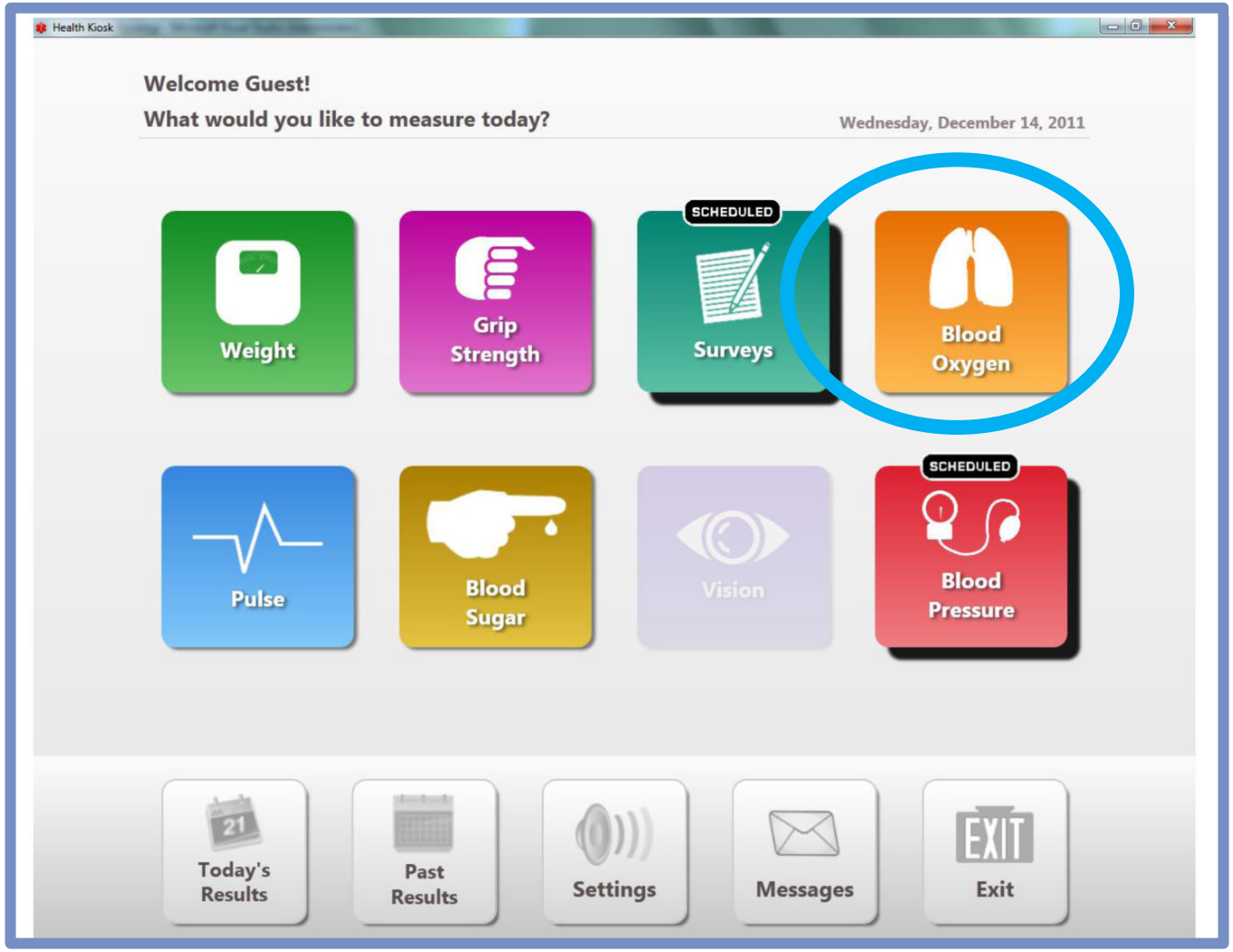
Health Kiosk: Multiuser kiosk for standardized health screening, assessment, and treatment delivery.

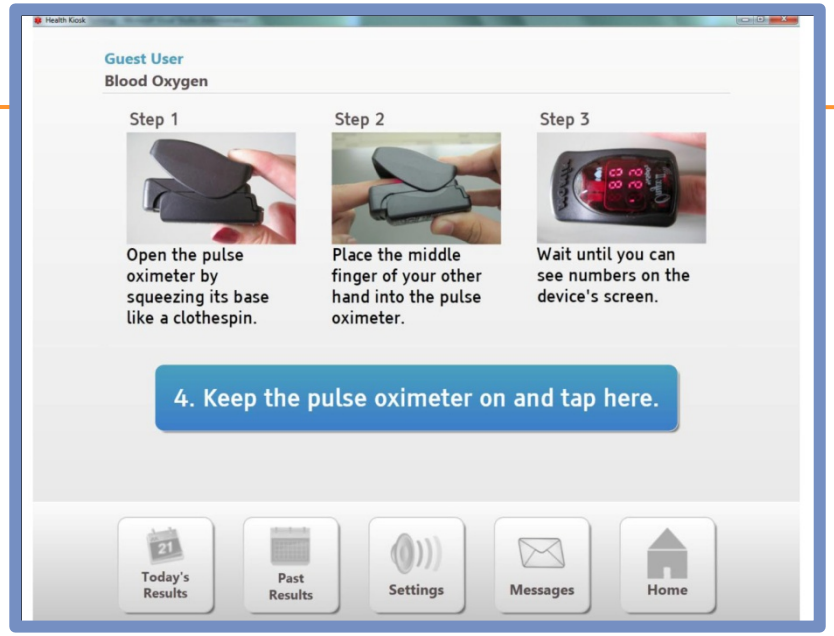
Functionality Of Health Kiosk

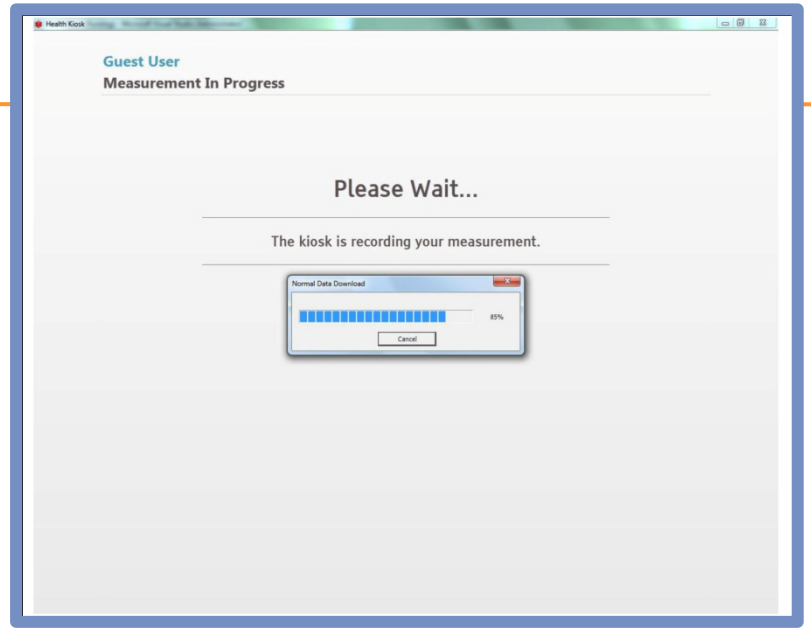


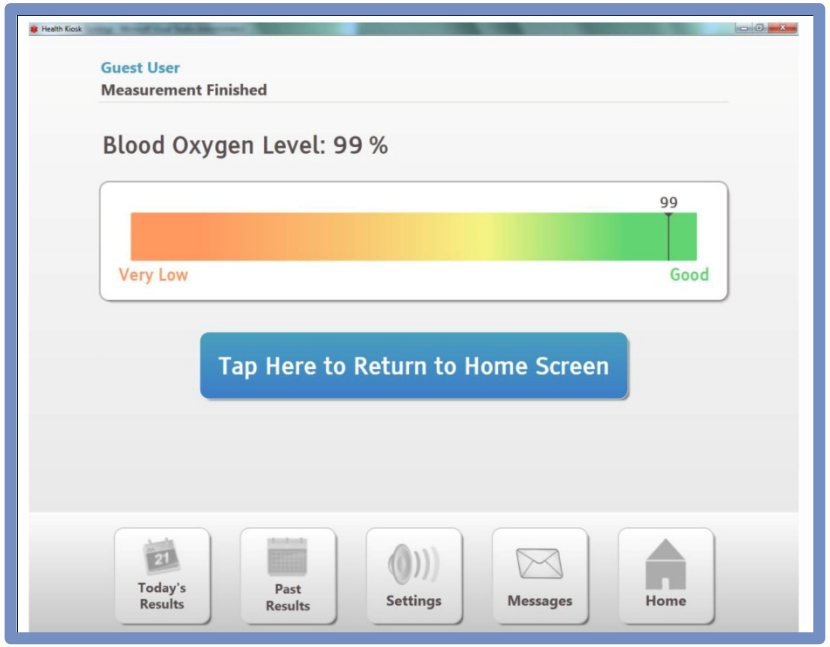


Kiosk: Home Page




Health Kiosk
Guest User
Blood Oxygen
Step 1
Open the pulse oximeter by squeezing its base like a clothespin.
Step 2
Place the middle finger of your other hand into the pulse oximeter.
Step 3
Wait until you can see numbers on the device's screen.
4. Keep the pulse oximeter on and tap here.
Today's Results
Past Results
Settings
Messages
Home


Health Kiosk
Guest User
Measurement In Progress
Please Wait...
The kiosk is recording your measurement.
Normal Data Download
85%
Cancel


Health Kiosk
Guest User
Measurement Finished
Blood Oxygen Level: 99 %
99
Very Low
Good
Tap Here to Return to Home Screen
Today's Results
Past Results
Settings
Messages
Home

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HeadCoach
A "Dosage" Monitoring Device For Home-Therapy Balance Exercises

Carnegie Mellon University of Pittsburgh

Gaze Stabilization Exercise

Figure 2A: Look straight ahead.

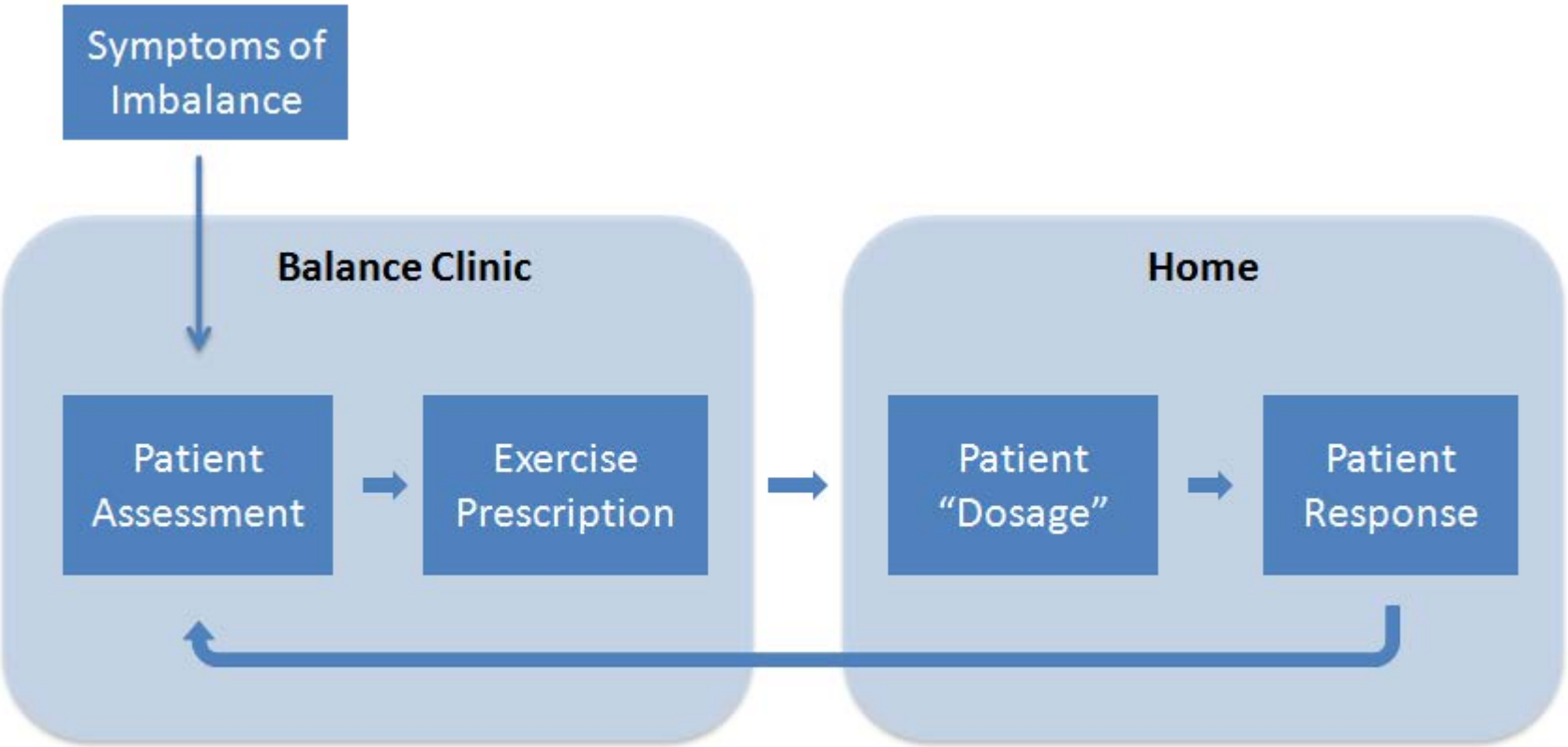
Figure 2B: Turn your head 45 degrees towards the right.

Figure 2C: Turn your head 45 degrees towards the left.

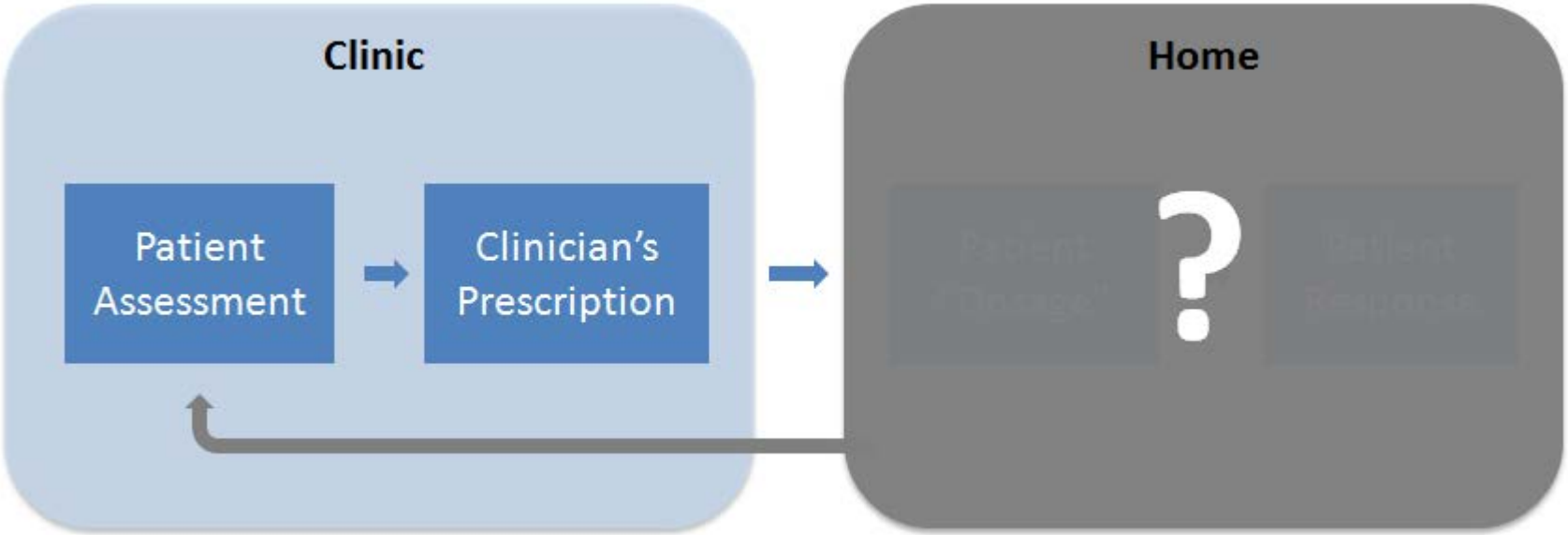
Note: Business card should be positioned at eye level.

Improves Vestibulo-Ocular Reflex (VOR)

Ideal Balance Treatment Cycle



Actual Treatment Cycle



Therapists cannot know what patients are actually doing at home

- "Dosage"
- Compliance

Common Problems and Mistakes

Performance

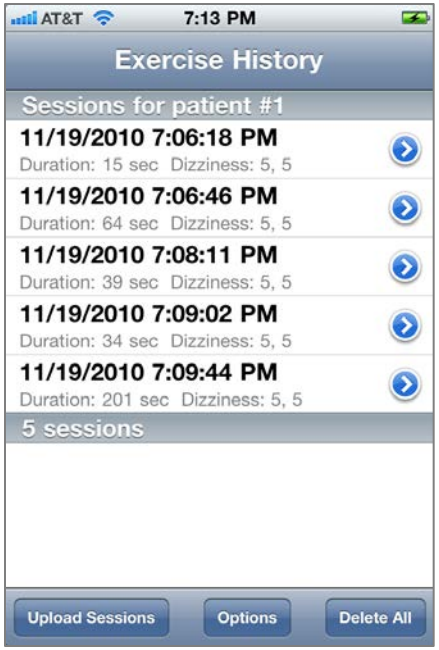
- Turning too fast or slow
- Moving eyes rather than head
- Turning too far to the sides and becoming dizzy
- Turning too little, negating the effectiveness of the exercise

Dosage

- Not following prescription outright
- Not remembering how much they did

HeadCoach


AT&T
7:04 PM
Dizziness Before Exercise
How dizzy are you right now?
7: Severe
6: -
5: Strong
4: Moderate
3: -
Save and Continue


AT&T
7:13 PM
Exercise History
Sessions for patient #1
11/19/2010 7:06:18 PM
Duration: 15 sec Dizziness: 5, 5
11/19/2010 7:06:46 PM
Duration: 64 sec Dizziness: 5, 5
11/19/2010 7:08:11 PM
Duration: 39 sec Dizziness: 5, 5
11/19/2010 7:09:02 PM
Duration: 34 sec Dizziness: 5, 5
11/19/2010 7:09:44 PM
Duration: 201 sec Dizziness: 5, 5
5 sessions
Upload Sessions
Options
Delete All


AT&T
7:35 PM
Back
Session Details
11/19/2010 7:15:51 PM
Dizziness Pre 7: Severe
Dizziness Post 4: Moderate
Duration 76 seconds
Realtime Playback
+3.0
+2.0
+1.0
0.0
-1.0
-2.0
-3.0
Play Back Session
Upload Session

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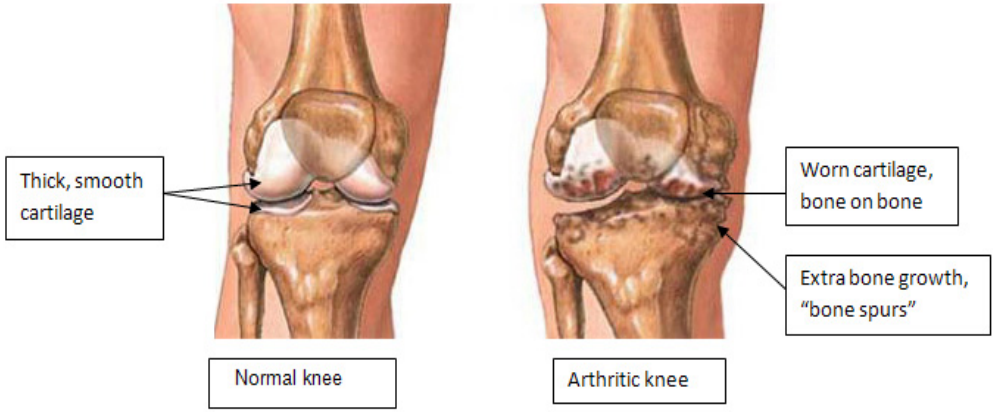
Personal Intelligent Coach: A Sensor-Based Therapeutic Coach for Home Rehabilitation of Knee Osteroarthritis

Carnegie Mellon University of Pittsburgh

The Problem

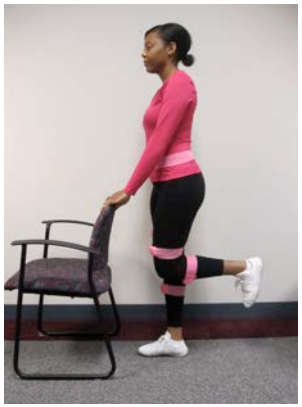
Problem:



- Knee OA is a degenerative disease
- Causes pain, swelling and decreased joint mobility
- Exercise is prescribed to lessen effects

- Home exercise intended as lifestyle change
- Poor adherence
- Incorrect performance

Measuring Quality



Standing
Hamstring Curl

Reverse Hip
Abduction

Straight
Leg Raise

Collect data from subjects performing exercises

Classifier trained to detect errors in exercise performance

Integrating Quality Assessment

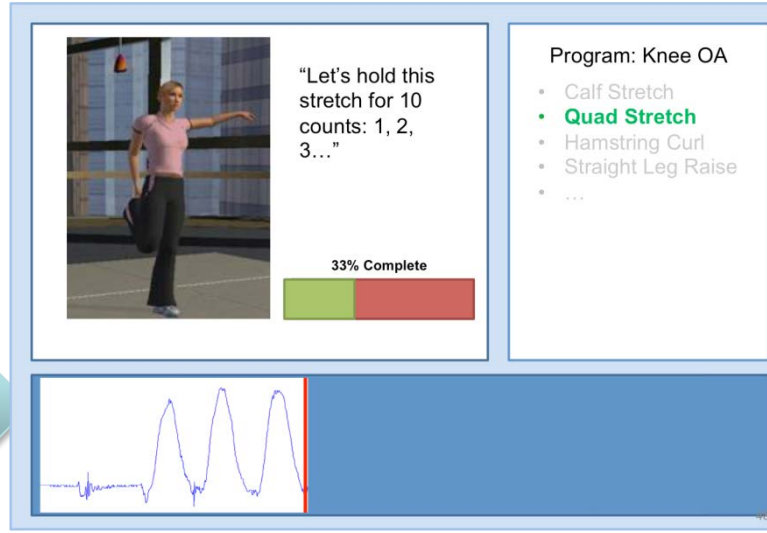
Sense

KINECT for XBOX 360

Depth Sensor

Gyroscope+ Accelerometer

Classification and Feedback



- Additional sensors can provide better measuring of quality
- Recognition of multiple errors in single performance
- Study possible forms of feedback to patient

Context Aware Virtual Coach

Context-Aware Virtual Coach

•Less than 35% of power-wheelchair users effectively use power-wheelchair functions to ease pressure sores [Lacoste et. al., 2003]

• The Virtual Coach artificial intelligence aims to help users better utilize the functions of their chair

• The chair must interact with the user in an **adaptive** and **personalized** manner

Project goal: Autonomously discover user preferences for modes and timing of instruction using onboard sensors.

Context-Aware Virtual Coach

Context Features
Physical location
Terrain type
Light sources
Audio characteristics
Date and time
Chair angles and posture
Air temperature

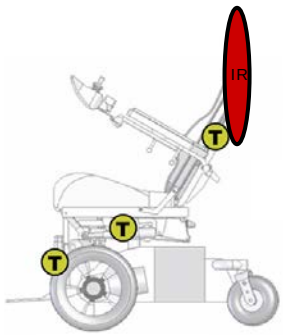
- **Support Vector Machines** with 6-axis accelerometer data.
- 87% classification accuracy over 5 terrains

- **Gaussian Mixture Model** using Cepstral coefficients detects noise in the environment and conducts speaker recognition.
- 90% accuracy in speaker recognition

•Evaluation will be performed in clinical tr
and **exercise compliance.**

Power Wheel Chair Virtual Coach

Pressure Ulcer



Sensing

Coaching

Activity	Parameter			Duration			Gap			Alert after
	Min	Ideal	Max	Min	Ideal	Max	Min	Ideal	Max	
Tilt	25°	30°	35°	25 sec	30 sec	35 sec	20 min	30 min	2 hrs	10
Recline	10°	15°	20°	4 mins	5 mins	6 mins	4 hrs	5 hrs	6 hrs	15
Feet Elevation	25°	30°	35°	50 sec	1 min	1min 10 sec	1hr 30 mins	2 hrs	2 hrs 30 mins	20
Pressure	0	60mm	200mm	0 sec	0 sec	30 mins	0 sec	0 sec	0 sec	5

General Tilt angle : Min 10, Ideal 20, Max 30
General Recline angle : Min 10, Ideal 30, Max 40

Prescription

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Augmented Feedback using Personal Robotics for Neuro Rehabilitation

Andrew Tran, Jason Tsay, Sheng Bin

Collaborators: Steve Kelly, Ela Lewis (Myomo)

Carnegie Mellon University of Pittsburgh

Motivation

Stroke

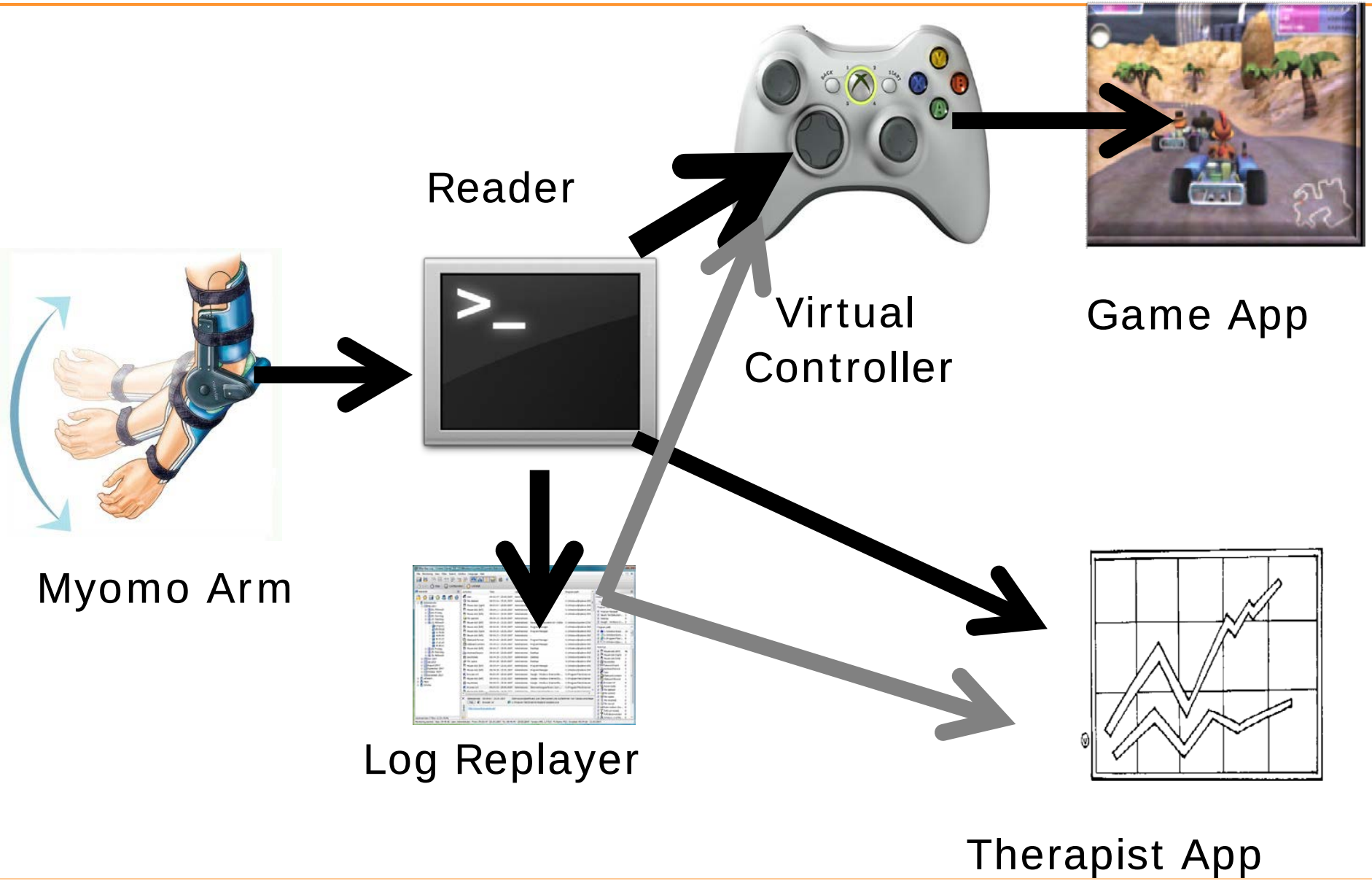
- Number one cause of disability in US
- 776,000 per year, total of 6.6 Million
- Cost $65.5 B per year
- 35% after hospital care

Project goal: Restore Arm Functionality

Problem Definition

How do we improve compliance by controlling video games with the Myomo arm?

System Architecture



Racing

Rhythm

Fighting

FPS

Speed

Shooter

JRPG

Platformer

Flight Sim

Arcade

Puzzle

Strategy

TD

IF

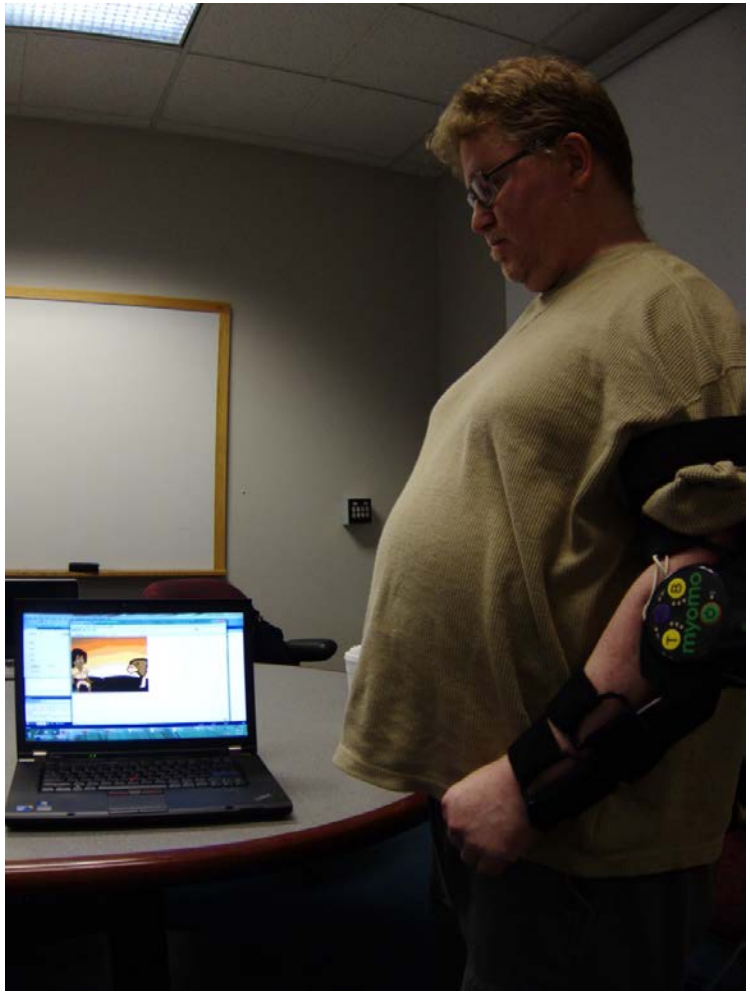
Control

Subject

Stroke victim – 6 years
Left side paralyzed
Likes Xbox and racing games
Tires in 3 minutes
5 repetitions suggested

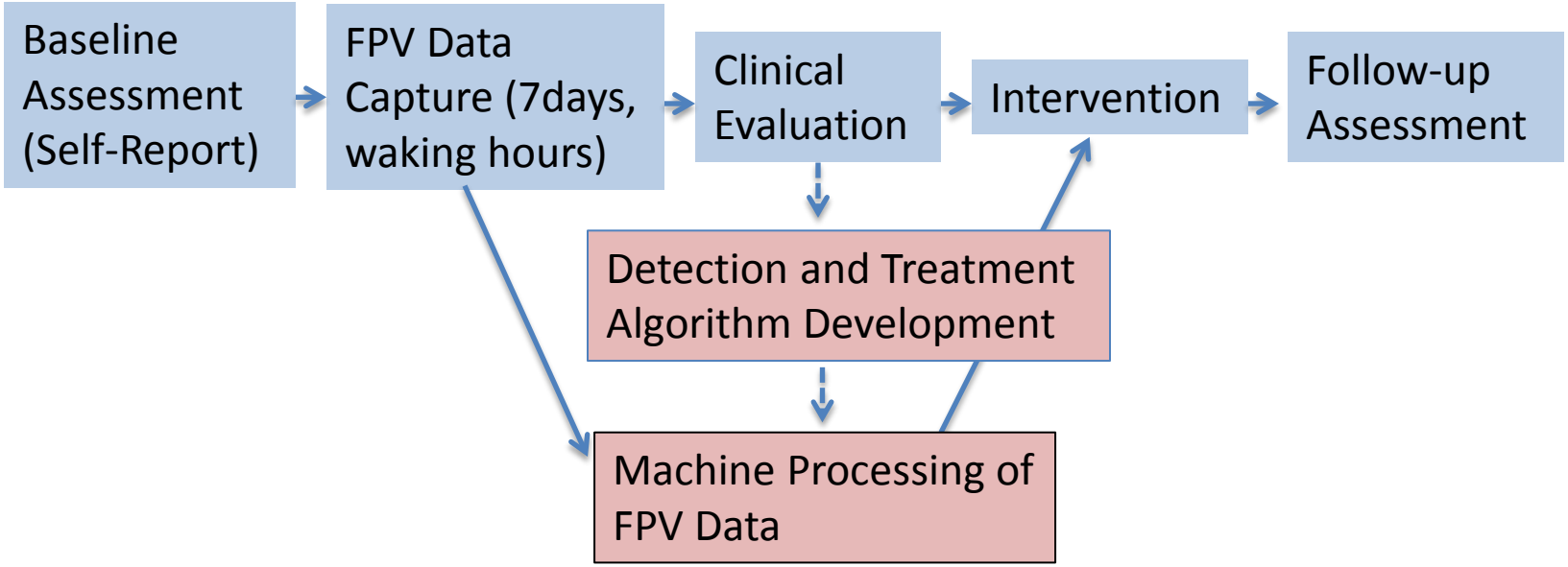
Insights

Can use both hands – good for rapid movement, assisted for selection
Hand collaboration seems to have cognitive rehabilitation as well



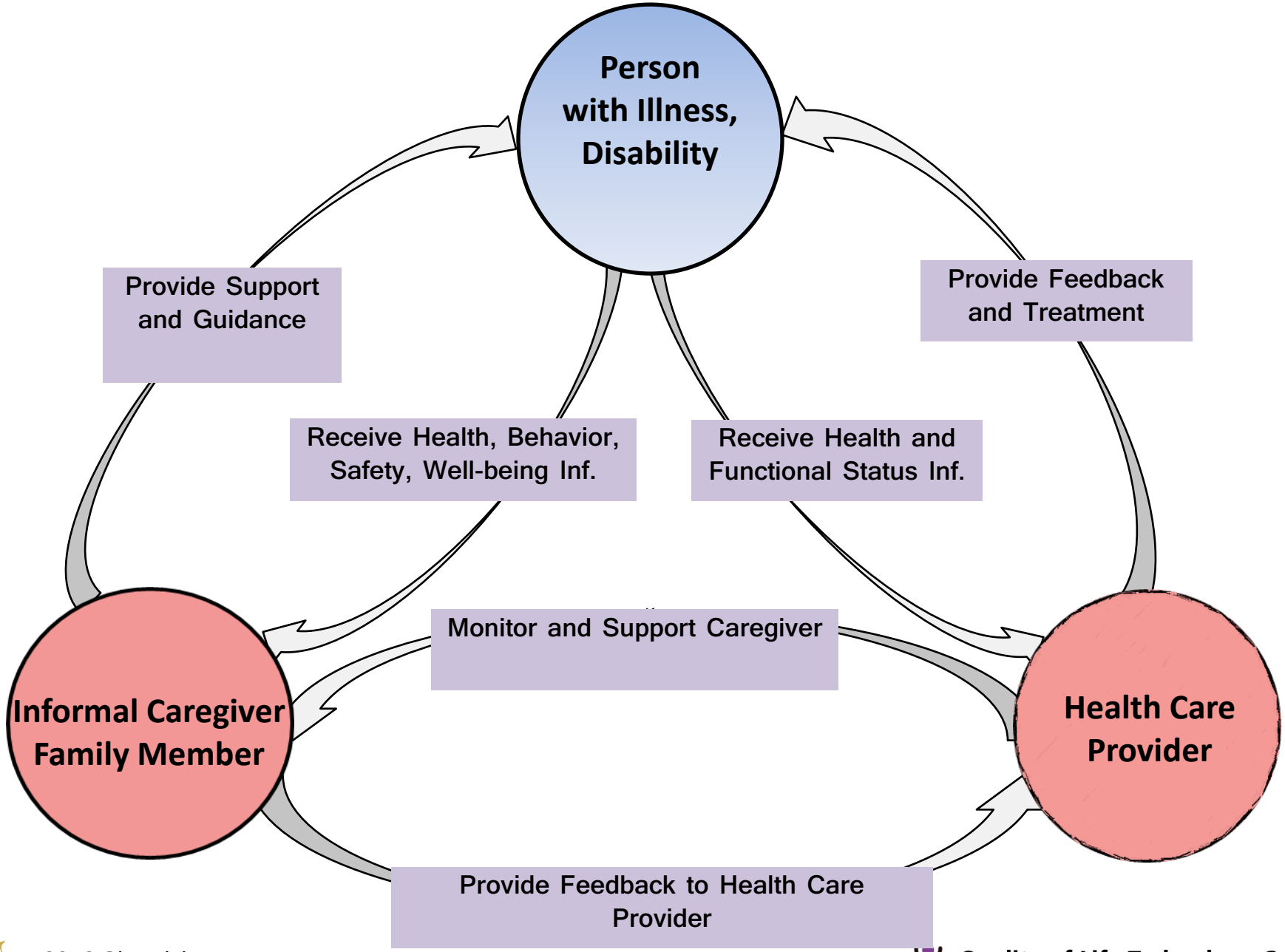
First Person Vision-caregiver application

FPV Caregiver Study Design for Dementia Patient Problem Behaviors

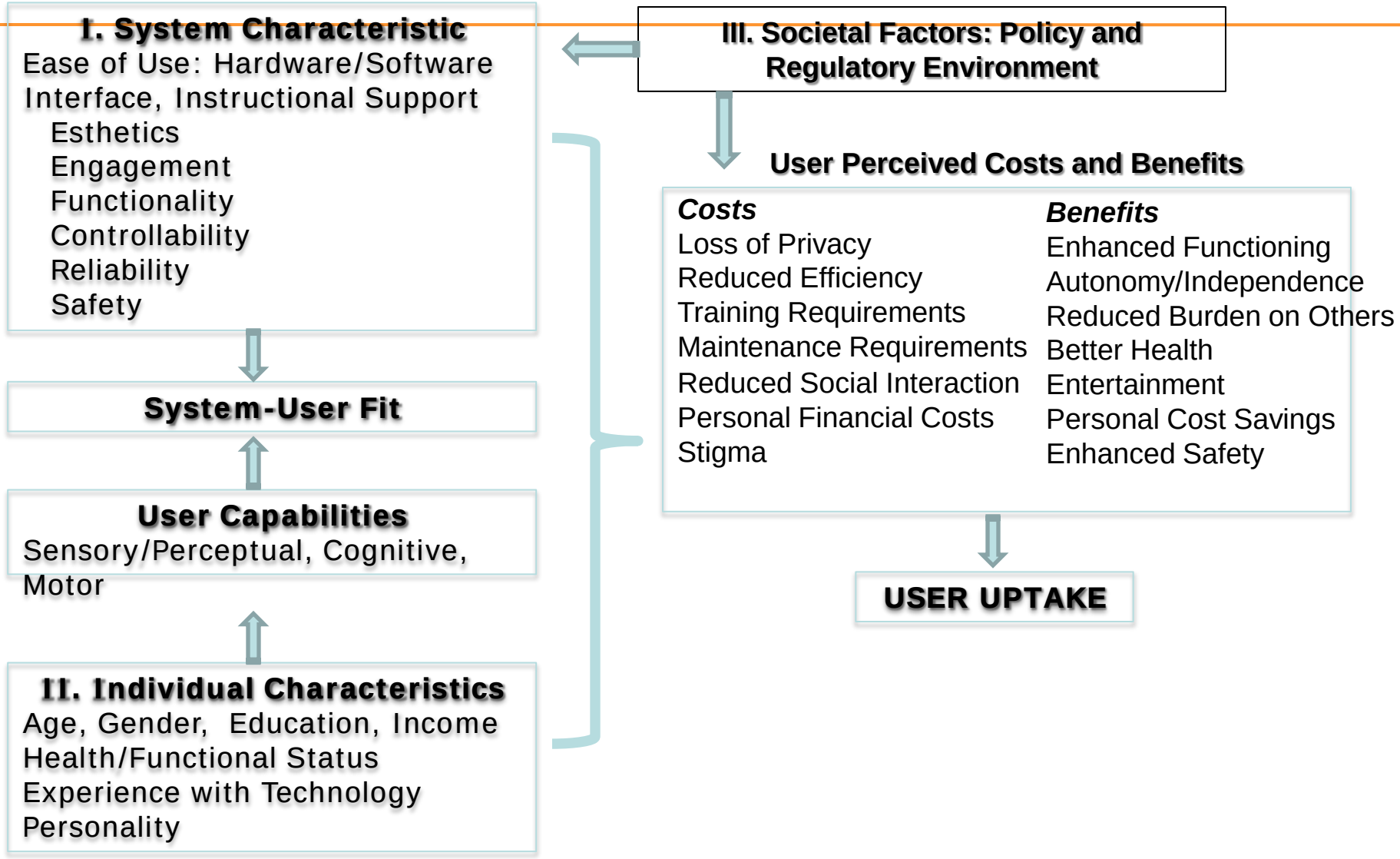


Repetitive Questioning

An Integrated Health Care Delivery System



III. Privacy/ System Demand and Cost



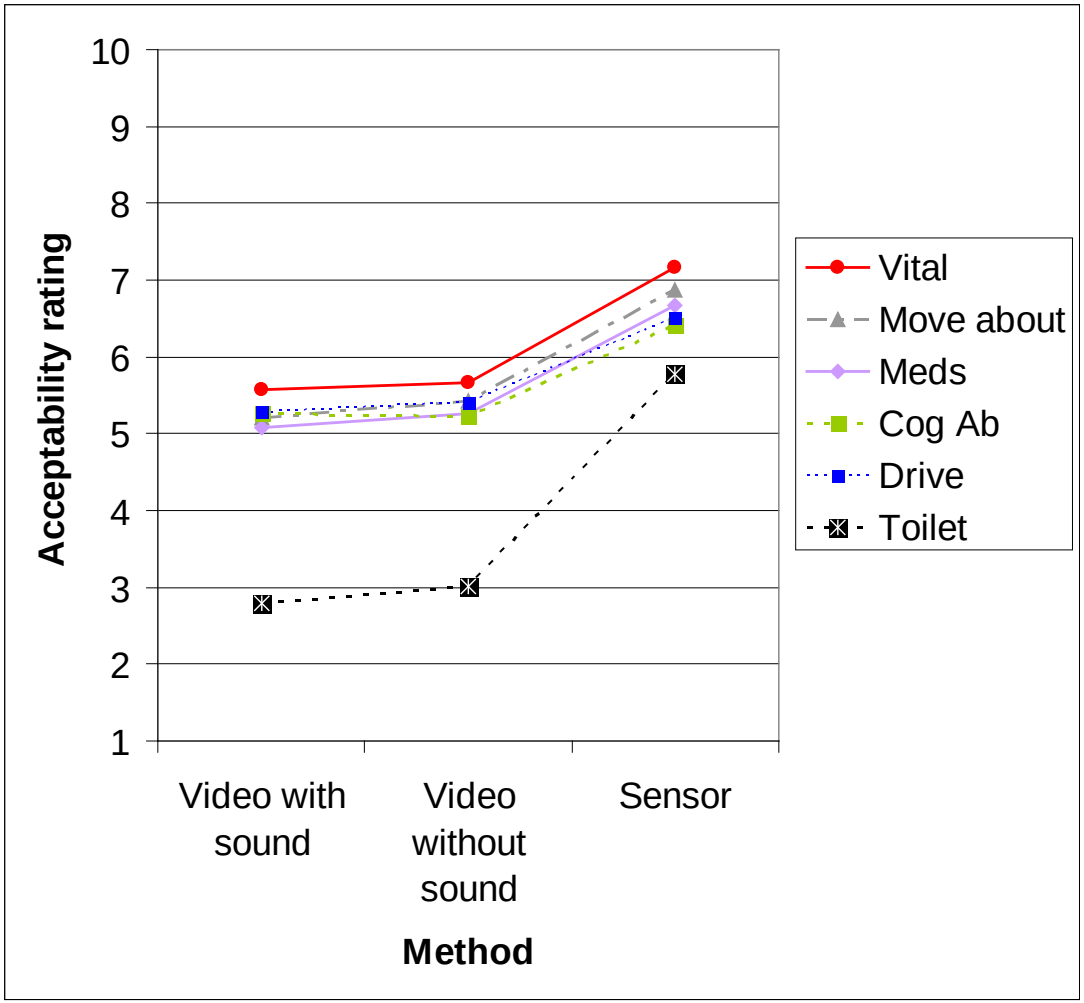
Model of Technology Uptake: System, Individual, and Societal Factors

Privacy Concerns

- How acceptable are different types of home and individual monitoring?
- How willing are individuals to share monitoring information with various targets (e. g. family, doctor, insurance co.)?
- How do functional gains (i.e., different levels of loss of independence) affect privacy preferences?
- How does current age, disability level, experience with disability, and education affect preferences?

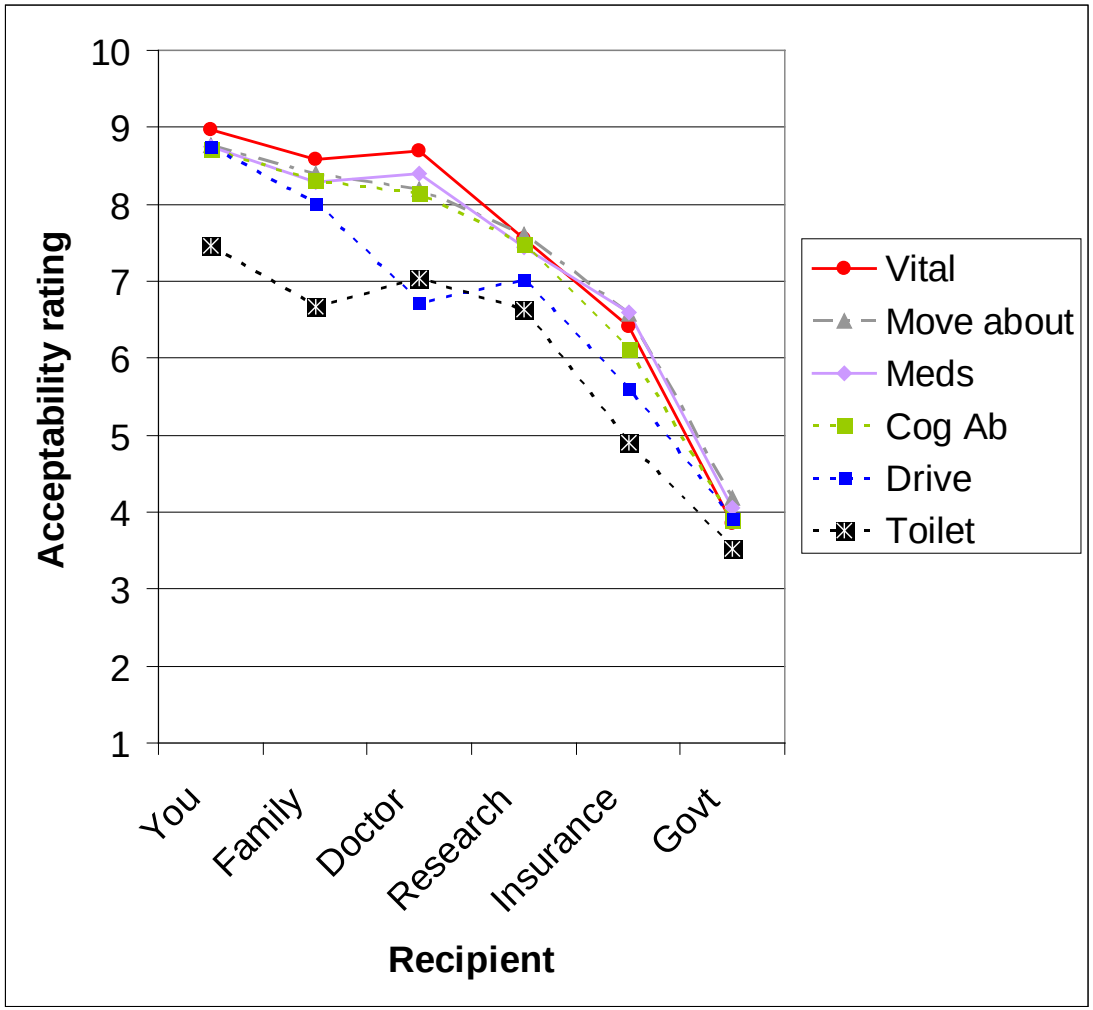
Privacy Results: Acquisition Method by Type of Data

- Video and video with sound less acceptable than sensors
- Some types of information (e.g., toileting) may be totally out of bounds for visual access

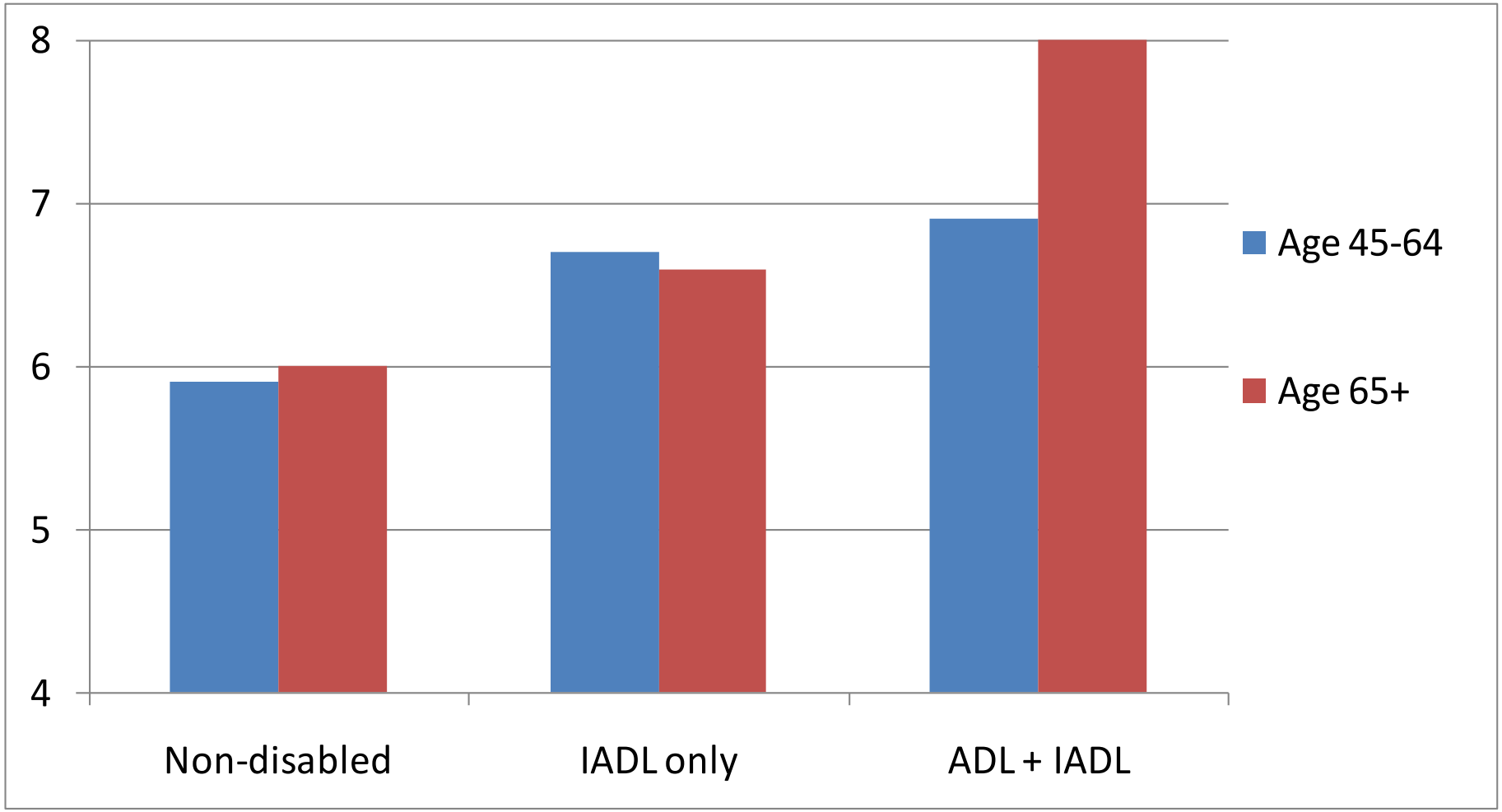


Privacy Results: Type of Data by Recipient

- Insurance companies and government least acceptable as recipient
- Driving information sensitive outside family contexts

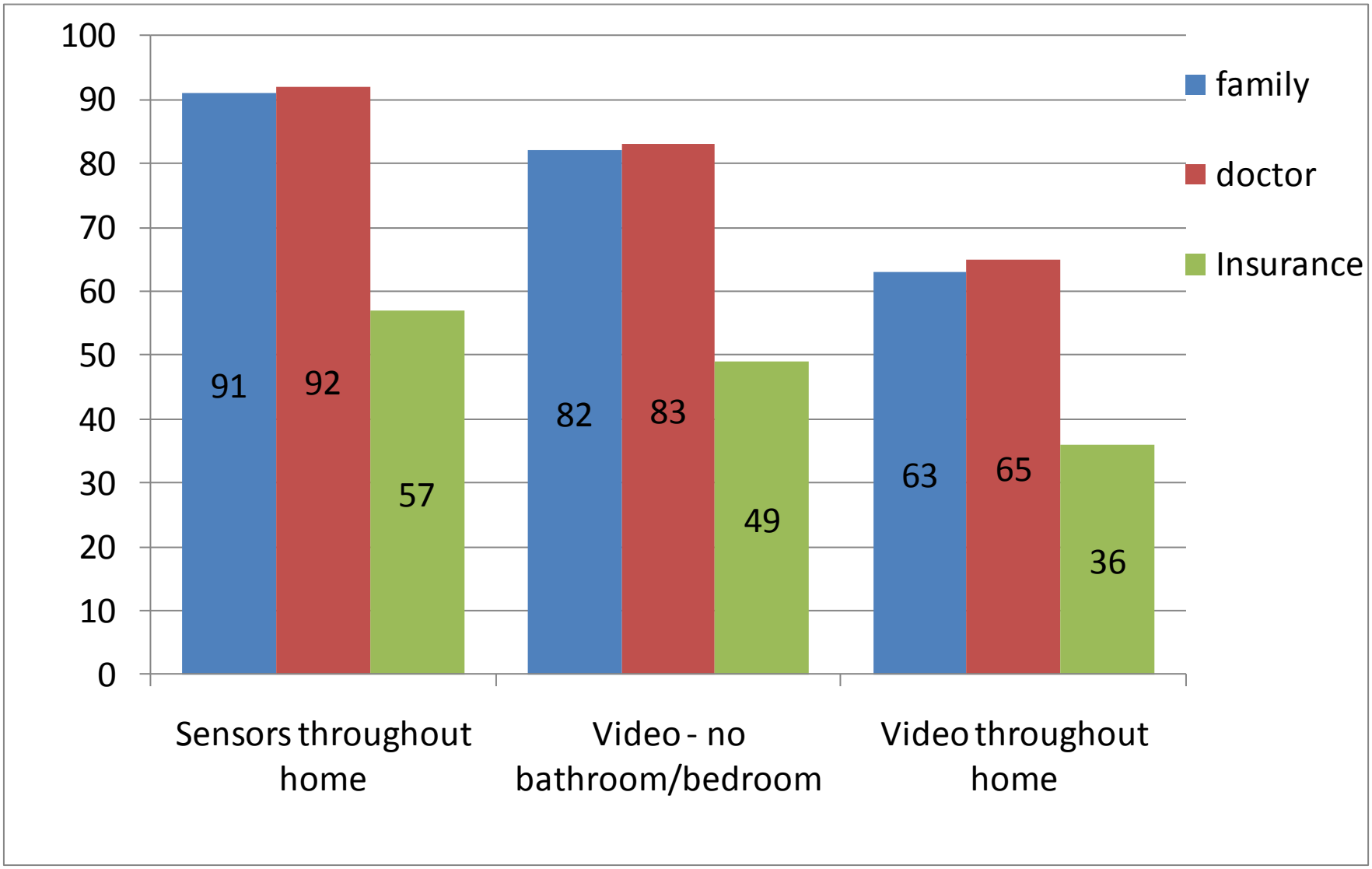


Acceptability of Sharing / Recording Health Information by Disability Level and Age

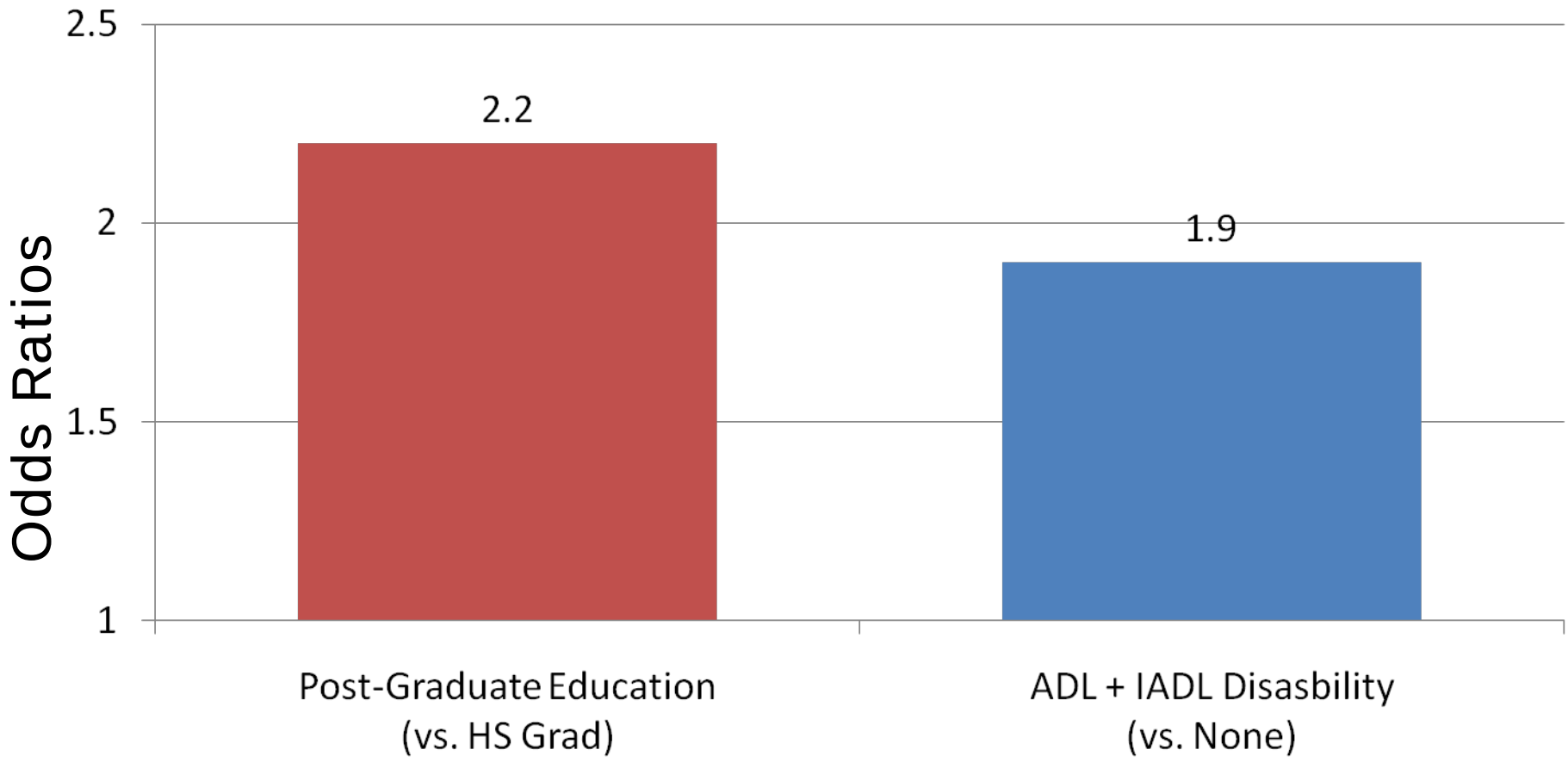


Controlling for gender, education, race, general technology attitudes, and assistive device use.

Acceptance of Differing Levels of Home Monitoring and Sharing Information with Varying Targets to PREVENT GOING TO A NURSING HOME

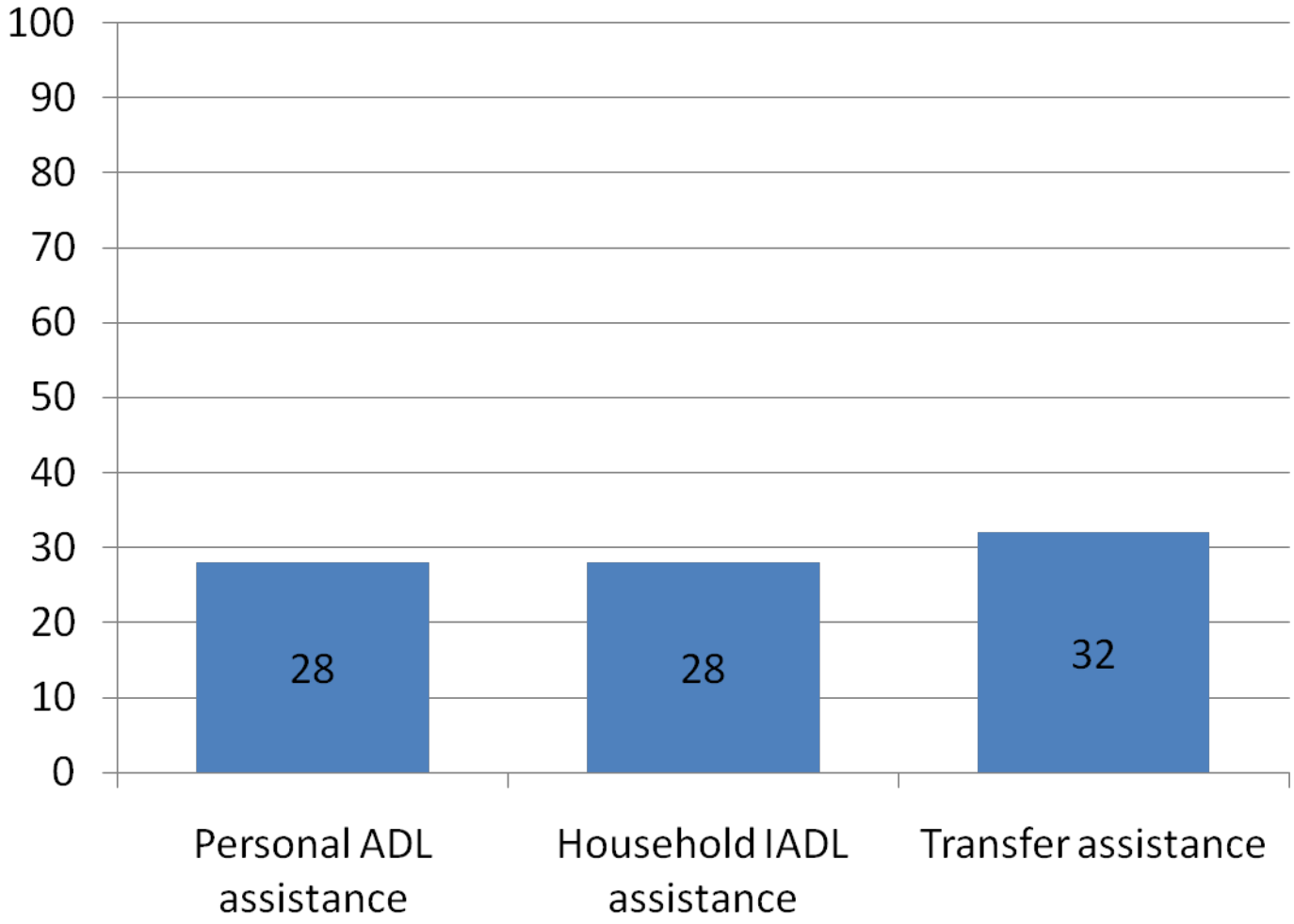


Significant Predictors of ACCEPTANCE OF VIDEO THROUGHOUT THE HOME to Provide IADL, ADL, or Transfer Assistance (Multivariate Logistic Model)



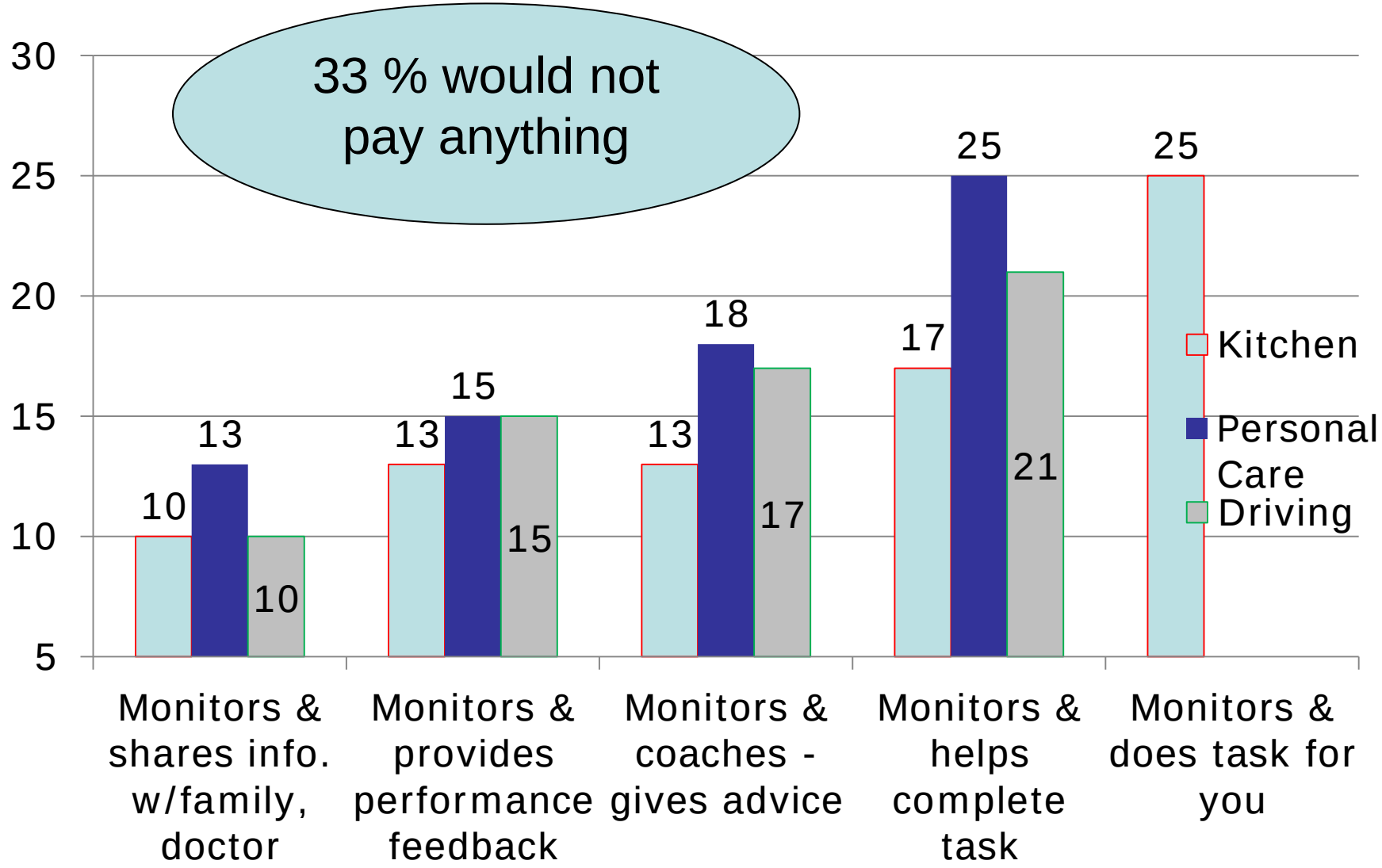
(Model controls for gender, age, and race)

Acceptance of REDUCED OPPORTUNITIES FOR SOCIAL INTERCATION with Technology Providing Varying Levels of Assistance

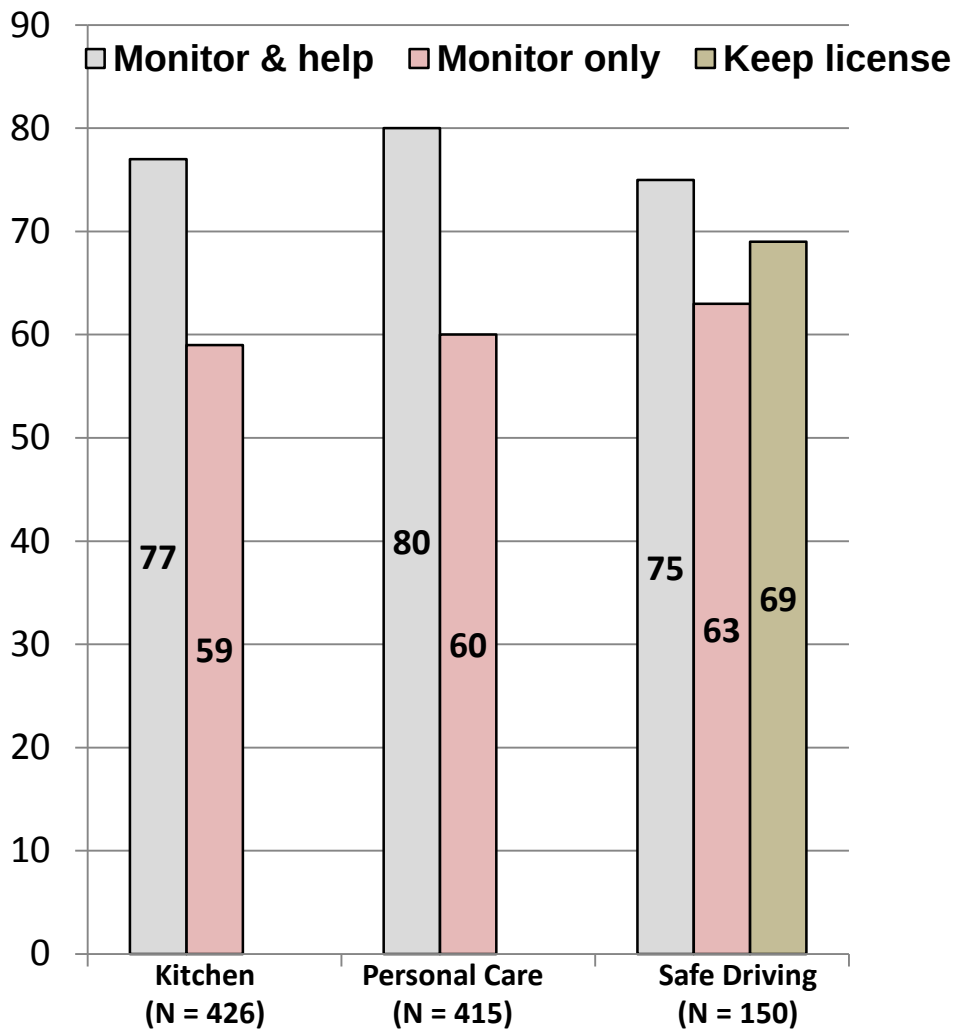


Who will pay? and How much will you pay?

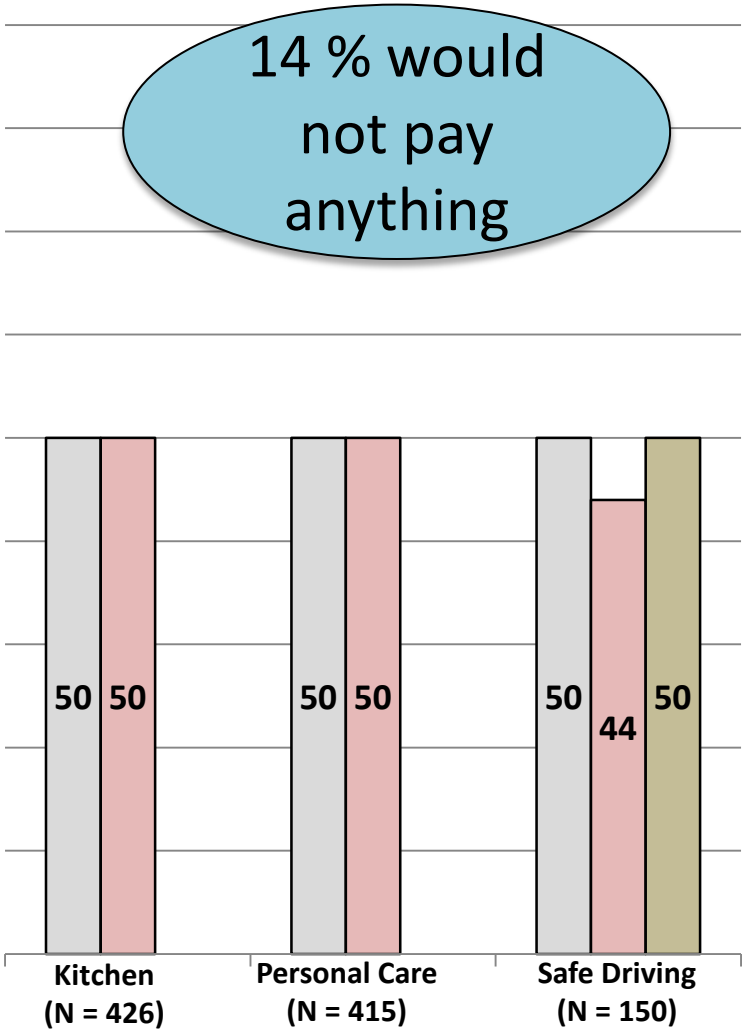
$ Amount WILLING TO PAY PER MONTH for kitchen, personal care, and driving technology performing various tasks (5% trimmed mean)—baby boomers and elders



Amount ($) Willing to Pay Monthly Out-of-Pocket for Kitchen, Personal Care, and Safe Driving Technologies, by Level of Assistance Provided (Among Those Willing to Pay > $0): Caregivers



5% Trimmed Mean



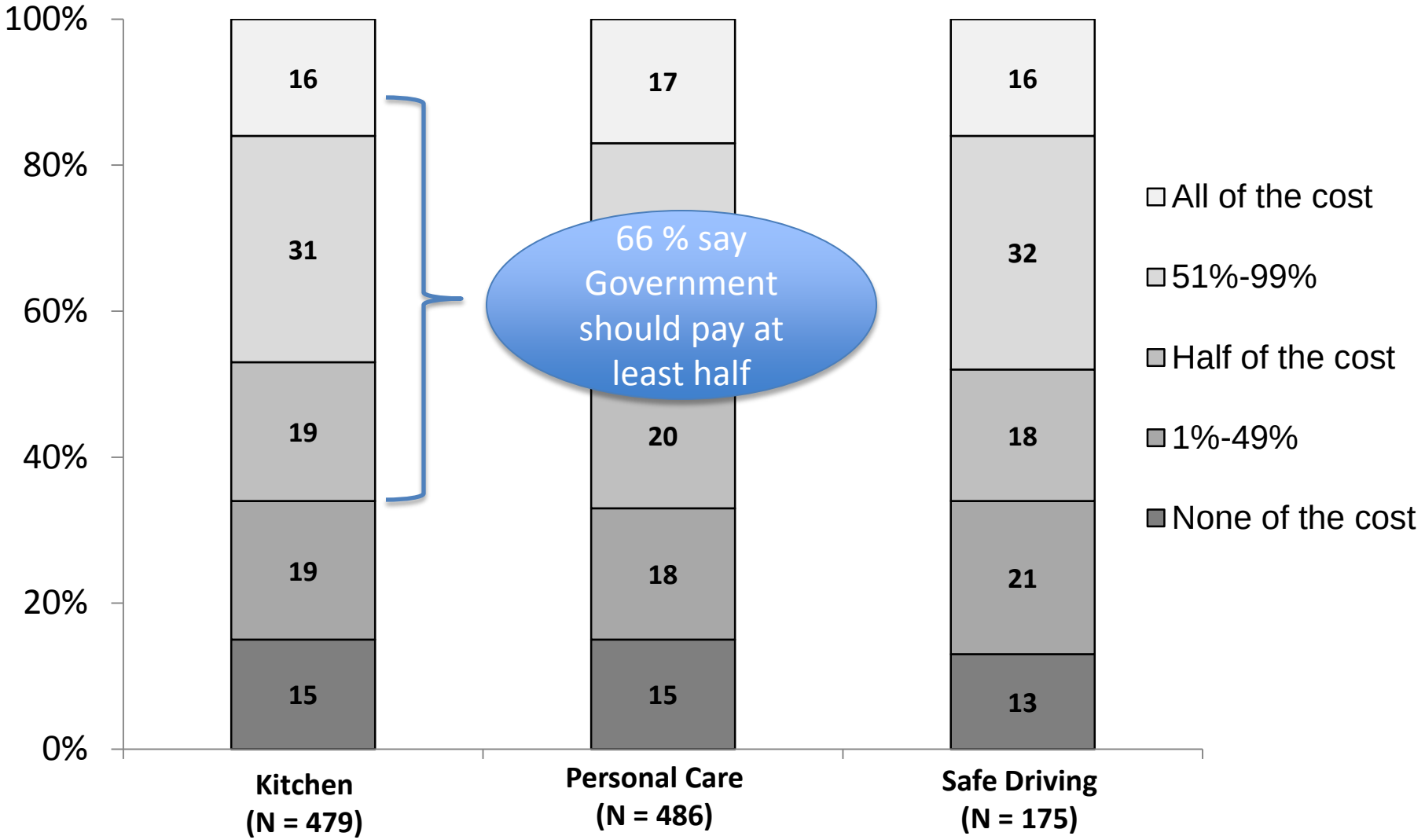
Median

Willingness to Pay Monthly Out-of-Pocket for QoLT to Receive Personal Help vs. to Aid in Caregiving for Kitchen & Personal Care Tasks

	Monitor and Help			Monitor Only		
	% Not Willing to Pay ($0)	5% Trimmed Mean ($)	Median($)	% Not Willing to Pay ($0)	5% Trimmed Mean ($)	Median ($)
Kitchen						
Boomers/older adults	35	28	20	55	26	20
Caregivers	12	77	50	15	59	50
Personal Care						
Boomers/older adults	32	38	25	49	29	20
Caregivers	13	80	50	16	60	50

Boomers/older adults from **2011 PST KN National survey of baby boomers and older adults**

"What percentage of the cost of this type of technology do you think the government should pay?"



Summary : Facilitators/Barriers

- Respondents less accepting of video monitoring – especially in bedroom and bathroom – than sensors; and of sharing information with insurance companies, even if they would prevent loss of independence

- Respondents generally rejected technology that limited social interaction and required intense training to learn how to use, regardless of the type of assistance provided by the technology

Summary: Facilitators/Barriers

- Disabled individuals are more accepting of sharing / recording health information than non-disabled (replicated with computer users vs. not)
  - Dose-response effect: ADL > IADL > Non-disabled
- Few age differences between boomers (45-64) and older adults (65+)
- Tipping point for acceptance of time to perform task: twice as long as human attendant (30 % drop in acceptability)
- Tipping point for acceptance of time for daily maintenance: 1 hour (40 % drop in acceptability)

Summary / Conclusions

- Current assistive device use not predictive of acceptance
- More positive general attitudes towards technology related to more acceptance
- Less educated were less accepting
- Cost is major barrier;

Product Development and Evaluation Timeline

User Needs and Task Analysis

User-centered Design Prototype → Robust Prototype → Laboratory Prototype → Field-deployed System → Commercially-viable Application → Commercial Product

Evaluation Design Strategies

L A B

User-centered design methods (Iterative)
Prototyping design and testing
Observation of task performance w/technology
Laboratory testing
Storyboarding
Rich stimulus displays
Scenario testing
"Wizard of Oz" studies
Individual in-depth interviews / "think aloud"
Focus groups/ Group-individual synthesis

F I E L D

Field testing
Pilot trial
Randomized efficacy trial
Effectiveness trial
Comparative effectiveness trial
Acceptance and adoption study

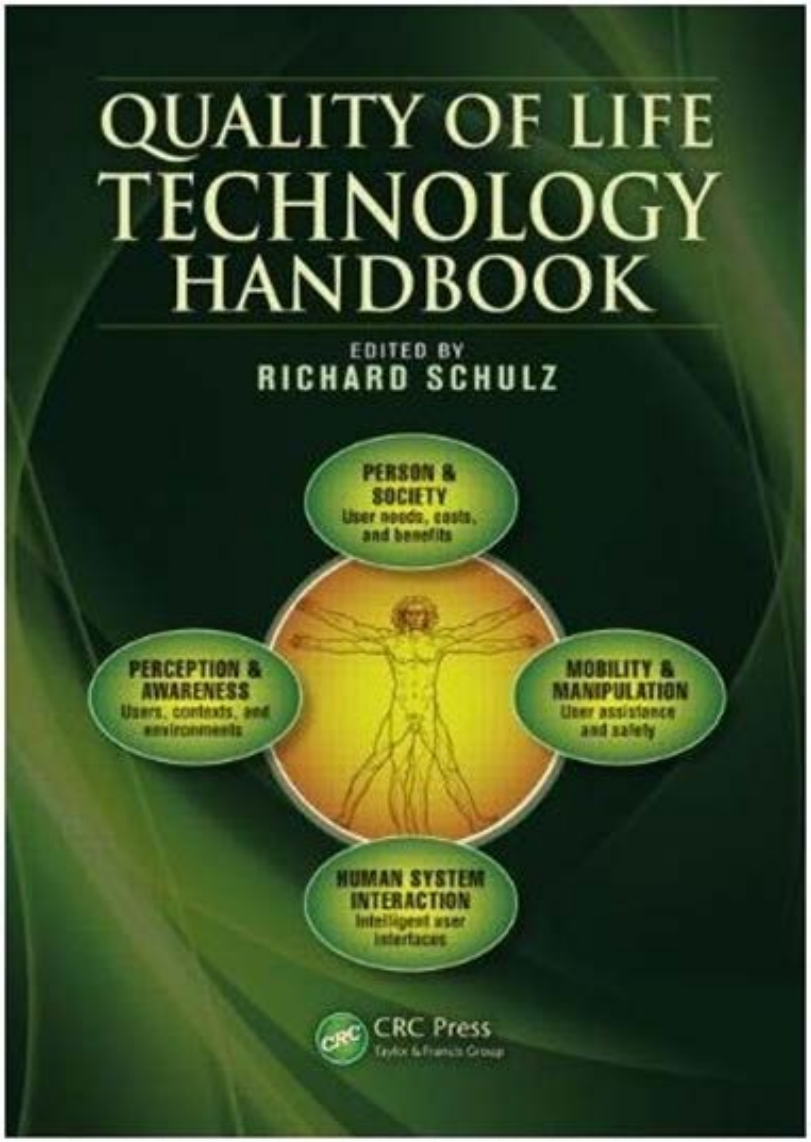
Measurement Strategies

Ease of use; Acceptability; Reliability; Learnability; Effectiveness; Efficiency; Errors; Flexibility; Memorability; User satisfaction; Safety; Confidence; Aesthetics; Convenience; Intrusiveness / privacy concerns

Adoption / uptake
Real-world task performance
Quality of Life
- *Technology-specific*
- *Disease/condition specific*
- *Generic*

Secondary / broad outcomes
- *Need for formal/informal caregivers*
- *Caregiver burden*
- *Healthcare costs*
- *Value to healthcare providers*

CRC / Taylor & Francis, 2013



Thank you—Questions?