Efficacy and Acceptability of Robots to Improve Physical Tasks in Hospital Environments

M. Cynthia Logsdon, PhD, WHNP-BC, FAAN[1]
Dan Popa, PhD[2]
Heather Mitchell, PhD[1]
Diane Chlebowy, PhD[1]
Indika Wijayasinghe, PhD[2]
M. N. Saadatzi, PhD[3]
Sumitkumar Das, BS[2]
(1)Nursing, University of Louisville, Louisville, KY, USA
(2)Engineering, University of Louisville, Louisville, KY, USA
(3)University of Louisville, Louisville, KY, USA

Robots as Nursing Assistants

Purpose

This project pushes the boundaries of science and technology by investigating the efficacy and acceptability ***of using robots*** to help professional nurses deliver healthcare.

Background

- Healthcare is considered one of the last industries to fully embrace technology that transformed other industries in the past 40 years.
- The Association of American Medical Colleges warned of a shortage of health care professionals of nearly 104,000 by 2030 [1].
- The use of robot assisted healthcare could help address this shortage by automating routine tasks and improving productivity and safety.
- However, research is needed that improves human and robot learning to collaborate in the safe, efficacious, and acceptable delivery of healthcare.

1. https://news.aamc.org/press-releases/article/workforce_report_shortage_04112018/

Background

- Developed by engineers on research team, an Adaptive Robotic Nursing Assistant (ARNA) is a mobile assistive robot that can navigate in cluttered hospital environments and perform chores as a nursing assistant.
- Some possible tasks are roles of patient sitter and walkers.
- From the robot's perspective, these skills still require a high level of intelligence, autonomy, and semi-autonomy to accomplish them in collaboration with a nurse. The necessary intelligence helps efficient communication with humans, autonomous navigation in hospital environments, accurate object identification, and manipulation.
- For this purpose, the ARNA is equipped with many sensors including cameras, 3D RGB-D sensors, LIDAR, multi-modal skin sensors, and force-torque sensors.
- With frequent advances in science and technology related to the sensors, development and testing of the robots must be iterative in order to reflect best practices for quality and safety in health care. Testing the use of robots with nursing students in a safe, laboratory learning environment provides a useful foundation for the next series of tests in an actual hospital environment with registered nurses and patients

Research Questions

1. What is the efficacy of ARNA's sensor systems (navigation, object detection, voice recognition, force detection, manipulation, adaptive physical guidance and assisted teleoperation) in patient sitter and patient walker scenarios?
2. Is the use of robots acceptable to nursing students in patient sitter and patient walker scenarios?

Theoretical Framework

- Theoretical Framework: The Technology Acceptance Model (Davis, 1989) served as the theoretical framework of the study.
- An integrative literature review demonstrated that TAM effectively predicts nurse's acceptance of health care technology (Strudwick, 2015).

Design

The study design is descriptive.

Sample

- Students (n=48) enrolled in basic undergraduate and second-degree nursing programs.
- Students worked in pairs, with one student acting as patient and the second student acting as nurse in the 4 scenarios.
- Each scenario (sitter and walker) was repeated 3 times on each date with different student pairs. Students received course credit for clinical/research hours from either NUR 330 undergraduate nursing research course or NUR 474 Culminating Capstone course for participating in the project.

Ethical Approval

The study has been approved by the university IRB. All students completed informed consents.

Procedure for Sitter Intervention

- A tablet with a custom programmed Android app was used to send commands to the robot to request 3 fetching tasks and assess the student's temperature and blood pressure.
- Nursing students either sat or reclined on the bed and interacted with the robot. As part of an effort to evaluate the task performance, the time to complete the task was recorded.
- The student was allowed to issue emergency stop commands during robot operation. Such commands are given priority and allow the robot to return to a safe position.

Procedure for Walker Scenario

- A patient walker walks alongside a patient providing assistance.
- Tasks performed by a patient walker may include watching for the risk of falls, applying supporting forces for comfort and navigation, pushing wheelchairs, and bringing along medical equipment such as IV poles and respirators.
- A robot providing patient walker assistance needs capability to: (1) assess the risk of falls by detection of deviation from normal walking patterns, (2) provide sturdy support for the patient, and (3) adaptively respond to the contact load and stabilize the patient. Additionally, a robot may need to push a gurney or bed transporting patients from one place to another in the hospital.

Instruments

- Data related to the efficacy of the robots was collected from each sensor by the engineering co-authors, including time to complete each task and accuracy of task completion.
- Efficacy was defined as full functioning of each sensor in each case scenario, with improvements in time and accuracy for the final two scenarios.
- Acceptability was measured using the two subscales of the Technology Acceptance Model (Davis, 1989), Perceived Usefulness and Perceived Ease of Use. Strong reliability and validity data have been demonstrated (Davis, 1989). Each subscale consists of 6 items in a Likert scale format with 7 response options from likely to unlikely. The Technology Acceptance Model is the gold standard for investigation of technology adoption in health care.

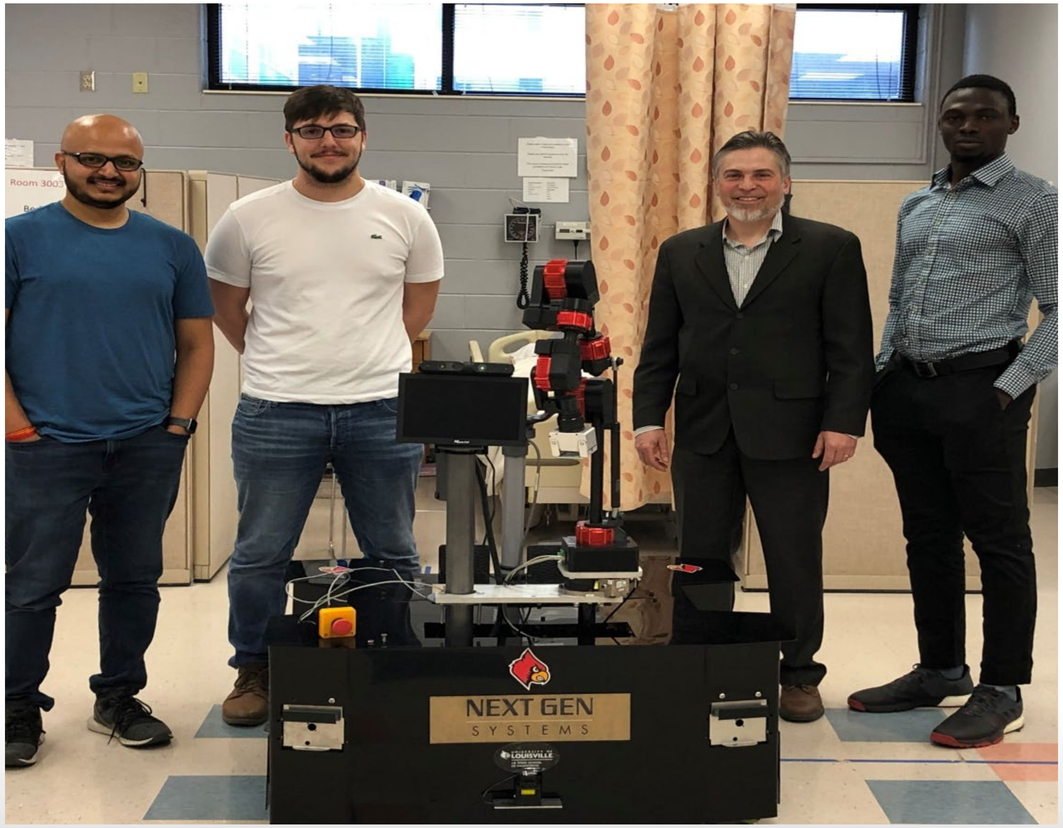
Efficacy of ARNA systems

Research Question 1:

What is the efficacy of ARNA's sensor systems (navigation, object detection, voice recognition, force detection, manipulation, adaptive physical guidance and assisted teleoperation) in patient sitter and patient walker scenarios?

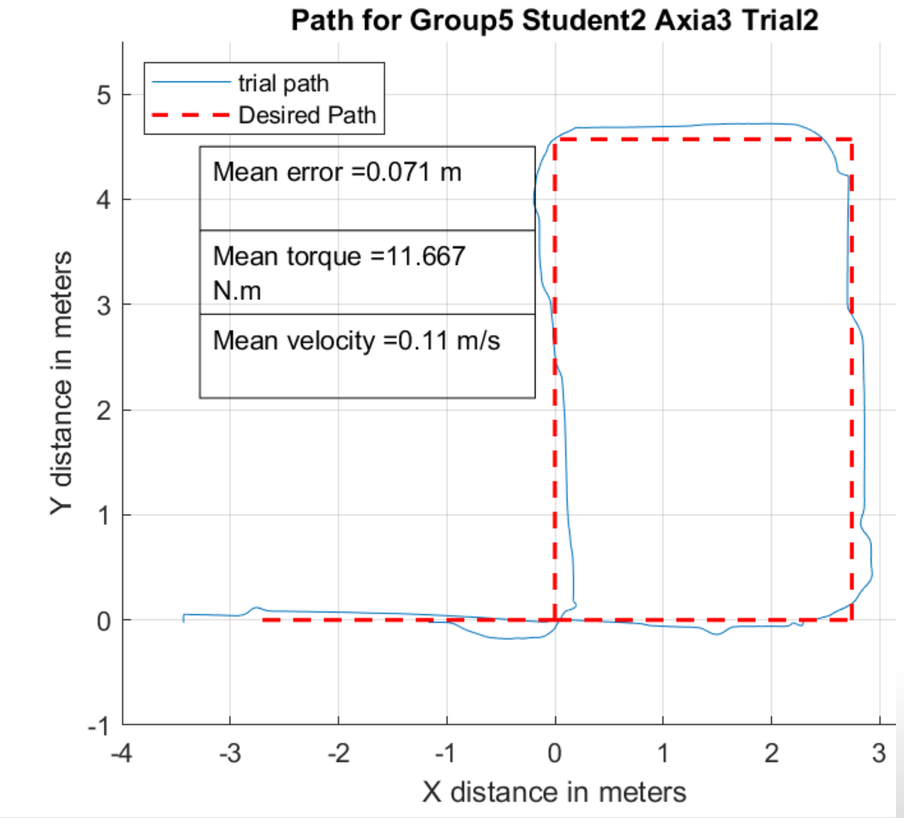
Efficacy of ARNA systems: Patient-Walker

- Navigation system: - F/T sensor, bump sensor, IR, ultrasonic, e-stop
- Fig: Video showing ARNA (navigating)

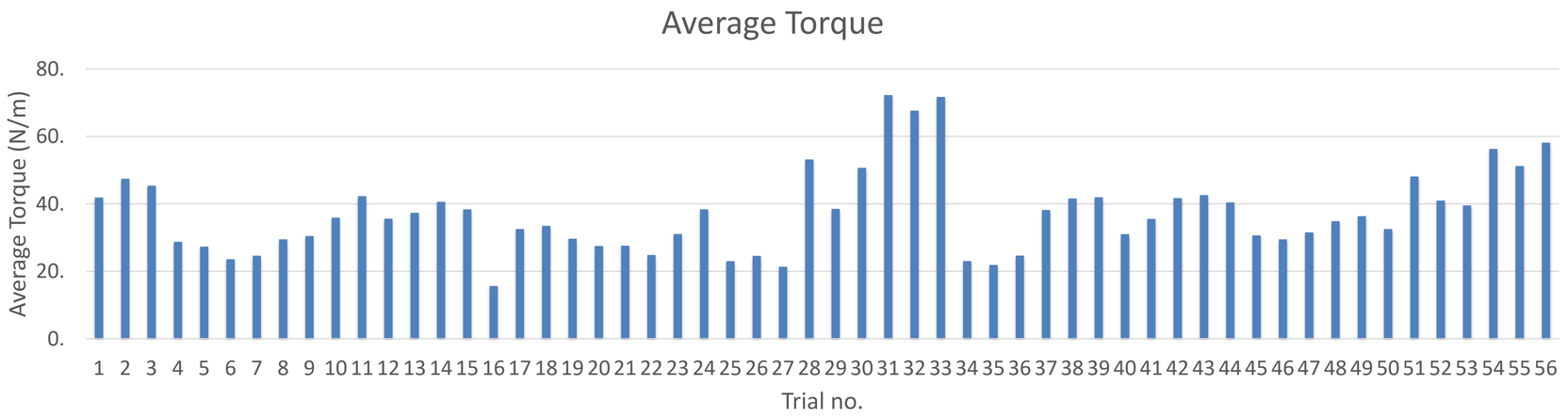


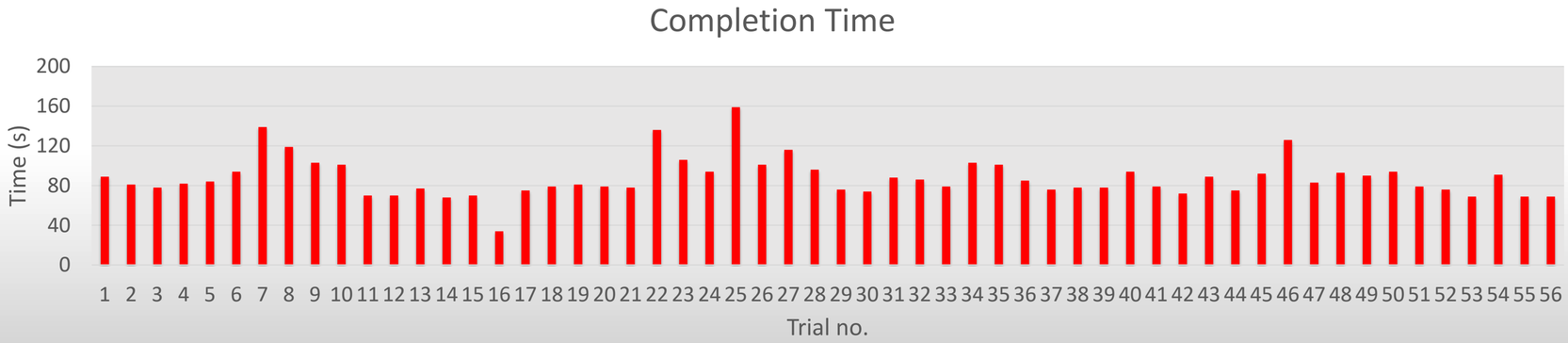
Efficacy of ARNA systems: Patient-Walker

- **Total distance:** 15.5m
- **Fig 1**: Plot showing path taken in a sample patient-walker run with some measures of the run



Efficacy of ARNA systems: Patient-Walker



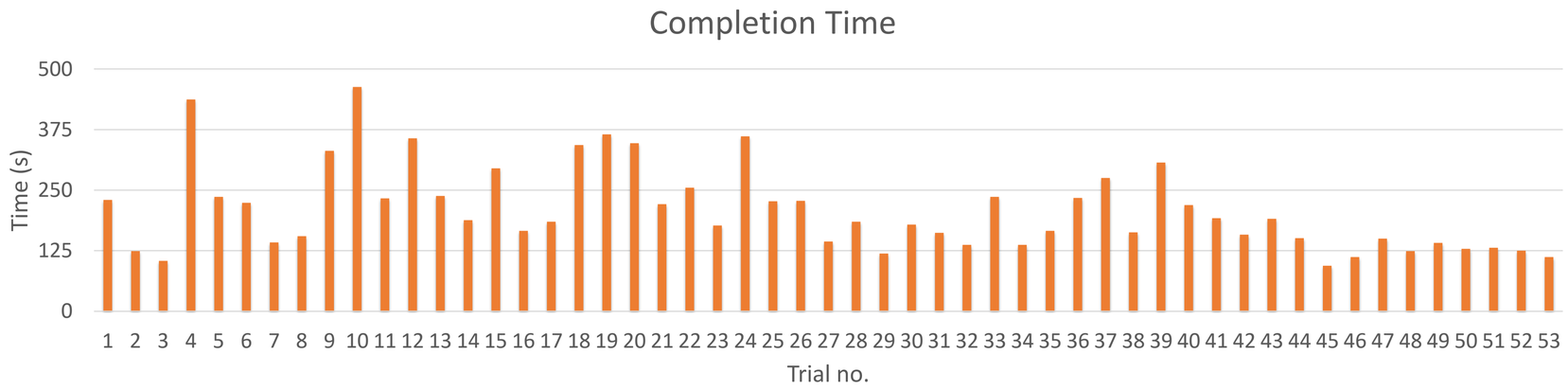


Efficacy of ARNA systems: Patient-Sitter

- Assisted teleoperation system: Remote operation, object Manipulation, Machine vision (to include LiDAR, object recognition. Currently, image feedback)

- Fig : Video showing ARNA being used as a sitter

Efficacy of ARNA systems: Patient-Sitter



Total distance: 13.5m

Acceptability

Research Question 2:

Is the use of robots acceptable to nursing students in patient sitter and patient walker scenarios?

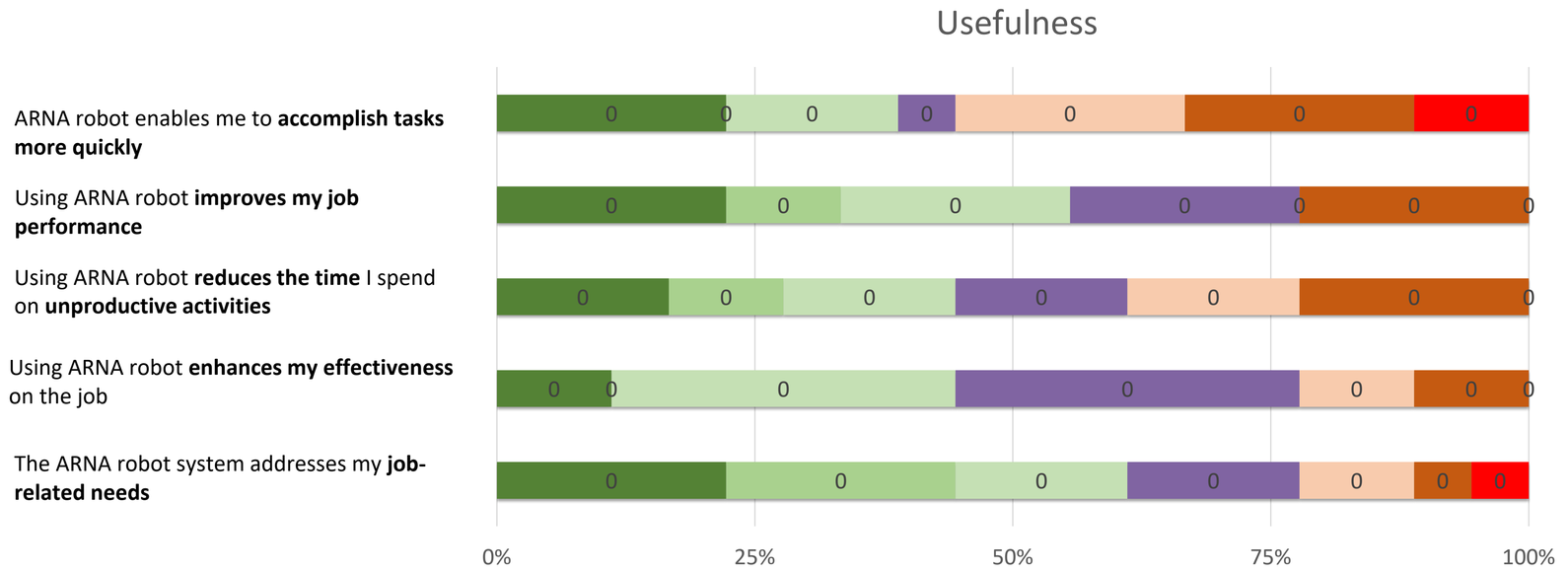
Table 7. Factor Analysis of Perceived Usefulness and Ease of Use Items: Study 2

Scale Items		Factor 1 (Usefulness)	Factor 2 (Ease of Use)
Usefulness			
1	Work More Quickly	.91	.01
2	Job Performance	.98	−.03
3	Increase Productivity	.98	−.03
4	Effectiveness	.94	.04
5	Makes Job Easier	.95	−.01
6	Useful	.88	.11
Ease of Use			
1	Easy to Learn	−.20	.97
2	Controllable	.19	.83
3	Clear & Understandable	−.04	.89
4	Flexible	.13	.63
5	Easy to Become Skillful	.07	.91
6	Easy to Use	.09	.91

Fig: Refined questions from TAM presented by Davis et al

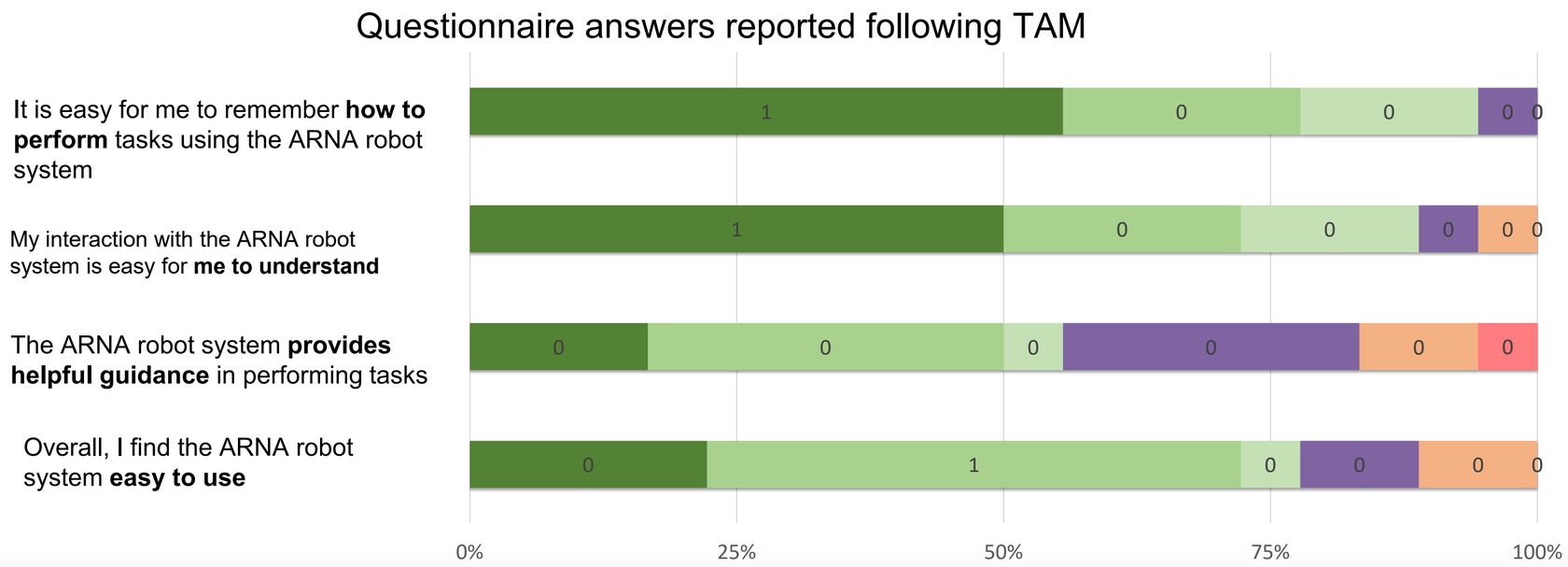
Acceptability

Perceived Usefulness



Acceptability

Perceived Ease of Use



Summary of Findings

- **Efficacy**
  - Navigation (Patient-walker): For the 56 trials,
    - Path distance = 15.5m
    - Path completion time : Mean 87.91s (Std dev = 19.99)
    - Average applied torque : Mean 37.23 Nm (Std dev = 12.11)
    - Considering that the robot weighs approximately 500 lb robot, the navigation system is rather efficient. With the robot also provides a instrument-carrying functionality (and eventually) more robust and dynamic ways to prevent falls, and is thus more useful than a typical walker and a good labor-reducing assistant for nurses. This idea is reflected in the Usefulness measure from questionnaire answers given by the test users.

  - Teleoperated navigation & manipulation (Patient-sitter):

While the teleoperated navigation is useful and easy to use (data), the current system design for object grasp was a bit challenging for users (refer to video). This results in a significant increase in the time of task completion (avg) and significantly impacts how they view the robot

Summary of findings

Acceptability

- Mean Perceived Usefulness : 4.4/7
- Mean Perceived Ease of Use: 5.77/7
- In [*], a PU mean of 4.7 and PEU of 5.07 and was used as a main basis for making a case that TAM results are a predictor of technology adoption

[*] Asua, José, et al. "Healthcare professional acceptance of telemonitoring for chronic care patients in primary care." *BMC medical informatics and decision making* 12.1 (2012): 139.

Future Work

- Include insights from answers of test users in making improvements to current design of Navigation, manipulation and control systems.
- Carry out more extensive user questioning and use extended TAM model to better understand potential adoption of ARNA

Conclusions

- Technology will continue to be used in health care organizations to enhance the effectiveness of the workforce and to ensure safe and effective health care for patients.
- Careful testing of the technology for efficacy and acceptability will provide evidence for effective purchasing and implementation decisions, and provide the evidence for change.

Efficacy and Acceptability of Robots to Improve Physical Tasks in Hospital Environments

M. Cynthia Logsdon, PhD, WHNP-BC, FAAN[1]
Dan Popa, PhD[2]
Heather Mitchell, PhD[1]
Diane Chlebowy, PhD[1]
Indika Wijayasinghe, PhD[2]
M. N. Saadatzi, PhD[3]
Sumitkumar Das, BS[2]
(1)Nursing, University of Louisville, Louisville, KY, USA
(2)Engineering, University of Louisville, Louisville, KY, USA
(3)University of Louisville, Louisville, KY, USA