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Smart Wheelchairs

February 26, 2019

Pooja Viswanathan, Rosalie H. Wang

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Conflict of Interest Declaration

Pooja Viswanathan is an officer of a new company that develops wheelchair accessories.

Rosalie Wang has no conflicts to declare.

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Overview

- Background
- What is a Smart Wheelchair?
- Smart wheelchair research
- Introduction to the SWAT Workshop
- SWAT Findings
  - Clinical practice and knowledge gaps
    - Case Application
  - Smart wheelchair sensors and algorithms
  - Clinical applications of smart wheelchair technology
  - Future research directions

Learning Outcomes

1. Participants will be able to describe a smart wheelchair, provide 3 examples of components and functions of a smart wheelchair, and 3 ways in which a smart wheelchair can increase driving safety and independence.
2. Participants will be able to describe 3 gaps in wheelchair assessment and training.
3. Participants will be able to discuss 3 design and ethical considerations for smart wheelchairs.

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Background

- Powered wheelchairs (PWC) provide opportunities for participation, health, quality of life
- PWC provision requires
  - Assessment of skills and abilities
  - Consideration of goals and needs
  - Clinical judgement
  - Training in device use for safety/competence
- Limited tools for PWC provision
  - Smart wheelchair technologies may offer opportunities

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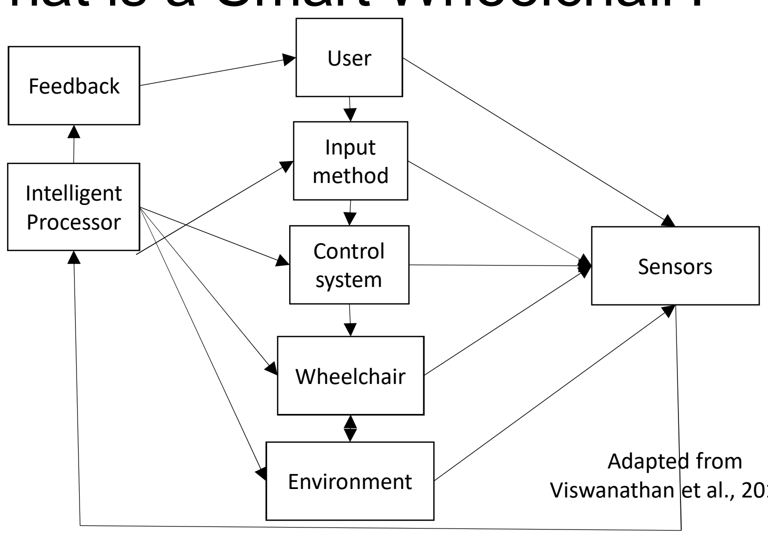
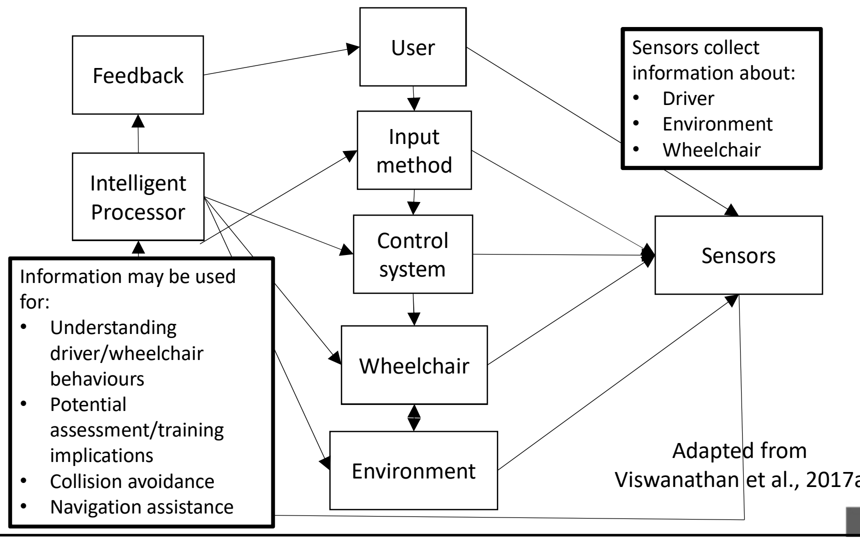
What is a Smart Wheelchair?



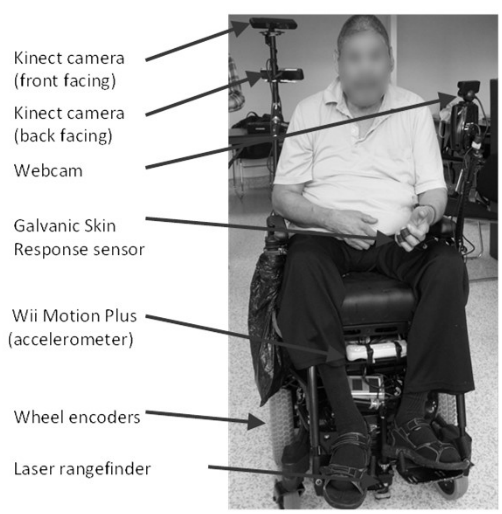
Adapted from
Viswanathan et al., 2017a

What is a Smart Wheelchair?



Adapted from Viswanathan et al., 2017a

Smart Wheelchair Technologies



Viswanathan et al., 2018

System	Participants	Test
Anticollision contact skirt (Wang et al., 2011)	5 adults with cognitive impairment	PIDA – manual vs. intelligent system
CARMEN (Urdiales et al., 2010)	30 adults with cognitive/physical impairment	Door passage – shared control only, Hallway – regular vs. shared control
Jiao Long wheelchair (Li et al., 2011)	5 adults with mobility impairment	Hall tour, Door passage, Collision avoidance
CWA (Zeng et al., 2008)	5 adults with CP or TBI	Realistic office environment (halls, doorways) with regular vs. assisted control
IWS (How et al., 2013)	3 adults with cognitive impairment	Obstacle course – regular vs. intelligent system
NOAH (Viswanathan et al., 2012)	6 adults with cognitive impairment	Maze with obstacles – regular vs. intelligent system

Limitations

- Relatively small sample size
- Little to no qualitative feedback
- Participant abilities are often not described in detail
- No evidence of iterative design, i.e. rapid prototyping, feedback from users incorporated in future design

Define Problem

Build Solution

Test Solution

Publish

Viswanathan et al. (2016)
Rushton et al. (2016)
Mitchell et al. (2014)

Methods

Tele-operator joystick

User joystick

Tele-operator visual interface

Methods

- Three modes (levels of control):
  - Basic safety(mode 1):
    - Slow down and stop if obstacle present (“docking speed” for parking and docking)
  - Steering correction (mode 2):
    - Steer away from nearby obstacles
    - Wayfinding prompts
  - Automatic (mode 3):
    - PWC drives on its own (participant can stop and resume)

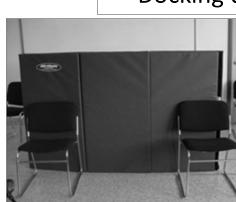
Methods

- Power Mobility Indoor Driving Assessment (PIDA) Tasks


Elevator


Docking under Table


Hallway


Back-in Parking


Manoeuverability

Methods

- 10 Participants at 3 LTC facilities in Vancouver
- About 14 hours / participant spread over two weeks
  - Pre-study assessments and data collection (2 hours)
  - Pre- and post-driving semi-structured interviews (3 hours)
  - 5+ driving sessions (9 hours) comprising three repetitions of each mode in each task (45 trials) + interviews

Key Findings

- Despite cognitive impairment, users are able to articulate some preferences and needs clearly
- Preferences vary between users and scenarios, and even for same user based on properties related to user, task, environment, and familiarity with system
- Highest preference overall for steering correction – better user experience than basic safety, while offering more control than automatic

STATE OF THE FIELD FINDINGS FROM THE SMART WHEELCHAIRS IN ASSESSMENT AND TRAINING (SWAT) WORKSHOP

Viswanathan et al.,
2018

SWAT Workshop

- Multi-disciplinary consensus workshop
- 31 ‘expert’ attendees (Toronto, Canada)
  - Engineers, computer scientists, clinical researchers, clinicians, a PWC vendor, a wheelchair controller manufacturer
- Small and large group discussions, survey, phone meetings, member checking of analysis

continued

SWAT Objectives

- Understand current clinical practice and knowledge gaps
- Review current smart wheelchair sensors and algorithms
- Discuss application of smart wheelchairs as tools for assessment and training and implications
- Propose future research directions

continued

Current clinical practice and knowledge gaps

- Powered wheelchairs currently seen as mobility devices only
- Assessment and training practices vary; limited validated tools for clinical use
- Often have barriers/restrictions placed on powered mobility
- Provision should consider goals of the client

Current clinical practice and knowledge gaps

- Key finding: Smart wheelchairs might allow PWC access to a larger number of people who are currently excluded.

Case Examples

Pediatrics

Older Adults

Smart Wheelchair Technologies

- Key Finding: Technological tools and data should be used to inform decisions by supplementing or complementing clinical tools and judgment, not by replacing them.

Application of Smart Wheelchairs to Assessment and Training

- Enhanced assessment
  - Standardized, quantified assessment tools
  - Valid assessment throughout the day
  - Long Term Monitoring
- Use in Training
  - Override/shared control
  - Identifying challenging tasks

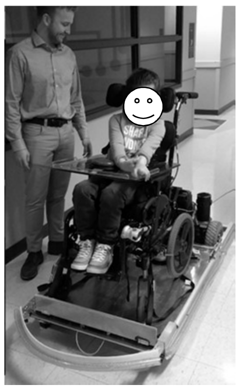
Application of Smart Wheelchairs to Assessment and Training

- Assisted mobility
  - Aid in driving, task completion (e.g., collision avoidance, doorway navigation, docking under tables, etc.)
    - Autonomous and semi-autonomous control

Application of Smart Wheelchairs to Assessment and Training

- Key Finding: Interdisciplinary approach is necessary to create tools that are effective, usable, and add value to all key stakeholders.

Case Examples:



Kenyon et al., 2017

Pediatrics

Viswanathan et al., 2017b

Older Adults

Why aren't there more smart wheelchairs in the market?

Challenges:

- Commercialization (sustainability)
- Integration into care

Current game changers:

- Lower cost of sensors
- More computing power
- More awareness from research re: benefits of powered mobility for different therapy goals
- More discussion of mobility as human right
- Self-driving cars!

Products in Market

https://www.smilesmart-tech.com/assistive-technology-products/smile-smart-wheelchair/

CALL Centre Smart Wheelchair, Smile Rehab

Nisbet et al., 1996

http://www.lisbethnilsson.se/en/tiro-the-learning-tool/

C300TIRO – The Learning Tool, Permobil Europe

Nilsson and Eklund, 2006

Products in Market

https://www.brazemobility.com

Braze Mobility Inc., 2017

https://www.tadibrothers.com/products/35-wheelchair-rearview-backup-camera-system

Tadi Brothers, 2003

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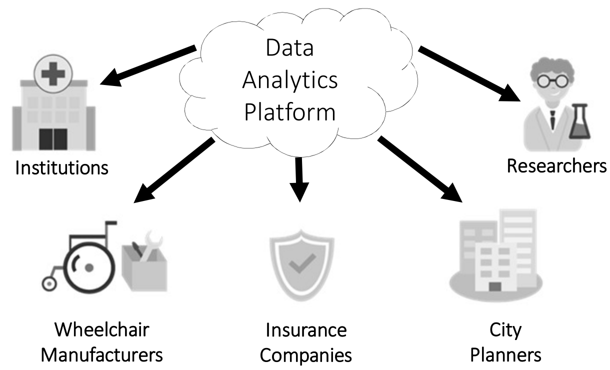

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Future Clinical Research Directions

- How can we distill all the information collected into meaningful data for clinicians?
- How do we decide who to remediate, and who to provide compensation for driving ability?
- Is it possible for a smart wheelchair to train a person to drive? What are the implications?
- How can we effectively get new technologies into practice… without waiting 17 years?

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High-level Consensus Statements

- Assessment and training are context-dependent
- Smart technology has a role to play when assessing and training users
- Smart wheelchairs can be modular, multi-modal, and multi-platform with a wide range of "smartness"
- Shared/collaborative control is a desirable (and perhaps necessary) feature in smart wheelchairs, but the method to implement this type of control is unclear

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High-level Consensus Statements

- Therapeutic use of smart wheelchair technologies is important
- Policy issues regarding access should be addressed
- Knowledge translation to help inform clinicians about possible technological solutions and educate researchers about challenges in clinical implementation
- Data sharing necessary to help move smart technology research development forward

Recommendations

- Strong collaborations, knowledge translation, and knowledge mobilization are essential in ensuring buy-in and adoption
- Existing and new research and development ideas should be evaluated by all stakeholders (e.g. clinical utility, engineering challenges, etc.)
- Balance low-hanging fruit with pie in the sky ideas to solve clinician and client needs

Learning Outcomes

1. Participants will be able to describe a smart wheelchair, provide 3 examples of components and functions of a smart wheelchair, and 3 ways in which a smart wheelchair can increase driving safety and independence.
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Questions?

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- SWAT report: http://agewell-nce.ca/publications/position-papers