Smart Wheelchairs in Assessment and Training (SWAT): State of the Field

Pooja Viswanathan, Rosalie H. Wang, Andrew Sutcliffe, Lisa Kenyon, Geneviève Foley, William C. Miller, Julianne Bell, Lee Kirby, Rich Simpson, Alex Mihailidis, Marlene Adams, Philippe Archambault, Ross Black, Julie Blain, Mark Bresler, Simona Cotarla, Yiannis Demiris, Ed Giesbrecht, Paula Gardner, Pearl Gryfe, Karen Hall, Christian Mandel, Kathy McGilton, François Michaud, Ian Mitchell, Ben Mortenson, Lisbeth Nilsson, Joelle Pineau, Emma Smith, Ellen Zambalde, Danny Zondervan, François Routhier, Tom Carlson.

Abstract

Smart wheelchairs are powered wheelchairs equipped with technologies that can collect information on powered wheelchair use, the driver, and interaction with the environment, and can use this information to modify wheelchair and/or driver behavior. These technologies could potentially be used to create tools to optimize design of training sessions, and aid in assessing various aspects of powered wheelchair navigation. However, the use of smart wheelchair technologies by clinicians in assessment and training is largely unexplored. The Smart Wheelchairs in Assessment and Training (SWAT) initiative was conducted with an international and interdisciplinary group of researchers, clinicians, and members of industry with experience in powered wheelchair intervention. After a literature review was circulated to the group, dialogues in a modified consensus workshop, a member checking survey, and a round table meeting led to the identification of several challenges in current clinical practice, potential technology solutions, and challenges in technology development and deployment. This state of the field report summarizes the initiative results, and suggests next steps in the research, development, and commercialization of smart wheelchair technologies for assessment and training of powered mobility use.

Introduction

Mobility is a key component in maintaining a high quality of life (Bourret et al., 2002). Individuals with physical impairments that prevent walking or self-propulsion of manual wheelchairs are often prescribed powered wheelchairs (PWCs) to allow them to navigate their environments independently. Decision-making regarding use of PWCs is based on several factors including perceived safety of the driver and others in the environment, perceived benefits to the driver, PWC accessibility, and funding models (Arledge et al., 2011). Individuals with cognitive/motor impairment, who exhibit symptoms such as inattention, decreased reaction time, poor judgment, and decreased visuo-spatial awareness, are especially likely to be excluded from PWC use due to safety concerns (Mortenson et al., 2006; Karmakar et al., 2012). Examples of diagnoses that can affect an individual's ability to drive a PWC safely include dementia, cerebral palsy, amyotrophic lateral sclerosis, traumatic brain injury, multiple sclerosis, and Parkinson's disease (Simpson, LoPresti, and Cooper, 2008).

PWC assessment involves a comprehensive review of the many factors which influence the readiness of an individual for PWC use, as well as the selection of an appropriate PWC to suit their needs and situation (Arledge et al., 2011). During and following the assessment, training on PWC driving skills must be effectively carried out to ensure the potential PWC user will be a safe, effective, and courteous driver (Arledge et al., 2011).

Although there is an overall lack of well-established tools to guide assessment and training that exhibit scientific rigour and clinical utility, there are a few existing tools which are highlighted in the literature. The Power-mobility Indoor Driving Assessment (PIDA) (Dawson, Kaiserman, Chan, & Gleason, 2006) and the Power Mobility Community Driving Assessment (PCDA) (Letts, Dawson, & Kaiserman, 1998) are clinically useful tools for PWC assessment and training in indoor and community settings respectively. They enable the clinician to assess areas for further training, environmental intervention, or device modification in order to improve an individual's PWC driving skills (Letts & Dawson, n.d.). The Wheelchair Skills Program (Dalhousie University, 2007), consisting of the Wheelchair Skills Test (WST), the questionnaire version of the WST (WST-Q), and the Wheelchair Skills Training Program (WSTP) is used to assess and train wheelchair users, and/or their caregivers and clinicians. The tools above were developed several years ago and have undergone several tests to ensure reliability, validity, and clinical utility (Dawson, Chan, & Kaiserman, 1994; Letts et al., 2007; Kirby et al., 2004; Rushton & Kirby, 2012; Kirby et al., 2015; Smith, Low, & Miller, 2017). These tools have also been utilized in other studies as a means of measuring PWC performance (Archambault, Sorrento, Routhier, & Boissy, 2013; Sorrento, Archambault, Routhier, Dessureault, & Boissy, 2011).

The "Driving to Learn" approach involves the use of a "training PWC" in combination with a tool involving an understanding of the incremental learning process and appropriate facilitating strategies to continue progressing the individual's learning. The tool acts as both a PWC assessment and training means for individuals with profound cognitive disabilities (Nilsson & Nyberg, 2003; Nilsson, Eklund, Nyberg, & Thulesius, 2011a). In terms of reliability and validity, the "Driving to Learn" method was determined to yield very good inter-rater reliability (Nilsson, Eklund, & Nyberg, 2011b). Overall, evaluation of the tool resulted in conclusions that the tool is a reliable tool for clinical use, particularly in the field of occupational therapy. The above work by Nilsson was recently combined with a tool developed by Durkin (2006) that assesses a child's stage of learning based on themes of attention level, emotional development, judgment, and lifestyle skills. This led to the consolidation of the Assessment of Learning Powered mobility (ALP) tool (Nilsson & Durkin, 2014), which has been translated into Swedish, Hebrew, Japanese, and German. The ALP assesses the learning process of an individual rather than specific mobility tasks, and provides strategies to facilitate learning. The creators of the ALP describe a core category "learning tool use" and a new theory of cognizing tool use to enable the application of the tool (Nilsson & Durkin, 2016). The ALP tool was applied to outcomes for study participants in (Kenyon et. al, 2015) to provide insights regarding progress made by each participant.

The Pediatric Powered Wheelchair Screening Test (PPWST) is designed to help prescribers evaluate a child's readiness to drive a PWC, based on their various cognitive skill sets (Furumasu, Guerette, Tefft, 2004). However, the PPWST is limited in its ability to predict a child's driving performance due to its sole reliance on cognitive skills, which are not the only variable influencing performance (Furumasu, Guerette, & Tefft, 2004).

The Obstacle Course Assessment of Wheelchair User Performance (OCAWUP) is another tool used to assess wheelchair skills, specifically those of a difficult nature (Routhier, Vincent, Desrosiers, Nadeau, & Guerette, 2004). Content validation for this tool was confirmed by using triangulation from three data sources in the tool's development (Routhier, Vincent, Desrosiers, Nadeau, & Guerette, 2004). Construct validity was also established as good for this tool (Routhier, Desrosiers, Vincent, & Nadeau, 2005). There is less literature highlighting this tool's clinical utility, however, compared to that of the other tools mentioned above.

The Power Mobility Skills Test serves as a tool to provide standardization and consistency to the assessment of individuals for potential PWC use, regardless of their age (Rico, 2014). During its development, the Power Mobility Skills Test was piloted across several Californian

counties in order to ensure its objectivity and ease of use (Rico, 2014). It is now mandatory for usage by all therapists in evaluating individuals for PWC readiness (Rico, 2014). Additional research is necessary to confirm the extent of its clinical utility, reliability, and validity in settings beyond the California Children's Services agencies.

Overall, there is no single standardized assessment or training procedure for power mobility which is considered best practice by PWC providers. Rather, there are a variety of resources available for power mobility assessment and training, which range in levels of scientific rigour, clinical utility, and scope of applicability within the PWC user population. For example, David Thompson Health Region published a set of guidelines on "Power Mobility Assessment and Safety Procedures" (David Thompson Health Region, 2012). These guidelines provide occupational therapists with a set of principles and procedures that outline who is eligible for powered mobility use, how to assess and train clients to use a PWC, how to handle incidents involving power mobility use, and when to reassess clients and/or remove their use of power mobility (David Thompson Health Region, 2012).

Given the lack of standardization in assessment and training protocols, the responsibility lies with the PWC provider to best determine their approach to evaluating readiness for PWC use, assessing driving performance, and conducting training interventions with clients. One study based on survey responses from three hundred and fifty-four professionals listed in the Rehabilitation Engineering and Assistive Technology Society of North America directory, who were qualified to conduct powered mobility skills assessments, revealed that the practitioners who recommend powered mobility devices mainly use non-standardized mobility skills assessments (Jenkins, Vogtle, & Yuen, 2015). Some degree of consistency possibly occurs within a certain jurisdiction or between therapists treating individuals for a similar condition, as they may utilize similar assessment and training tools within their facilities or jurisdictions.
Further investigation is necessary in order to conclude whether this lack of standardization in assessment and training processes is an issue for clinicians and PWC users. Given the extent of variability of needs, goals (of both the PWC user and therapist), circumstances, and environments between clients assessed for power mobility, the development of a standardized assessment and training procedure for all potential PWC users may be unattainable and inappropriate. The lack of standardization gives PWC providers the necessary flexibility to individualize their assessment and training procedures relative to their specific client. However, considering the current push within health care for evidence-informed practice, a lack of standardization may raise questions regarding the availability of evidence to optimally guide assessment and training procedures in practice.

Individuals looking to receive a PWC may experience a high degree of variability in PWC access due to inconsistent assessment and training procedures across jurisdictions. Clinicians involved in assessment and training often would like more tools or resources in order to guide their decision making and training practices. This is especially true in cases that are borderline, where clients may be unduly restricted from access based on current assessment and training procedures. Thus, the development of standardized assessments of specific and minimal skills/abilities in addition to a toolkit of assessment and training tools for different populations would likely be helpful in addressing some of the aforementioned issues.

Although there is no formal standardization for PWC assessment procedures across jurisdictions, the assessment tools described earlier generally collect similar data and could therefore lead to fairly consistent clinical decisions. For example, the majority of assessments require several trials of various PWCs in order to test for various PWC skills. These trials produce a performance score which is typically quantitative, although the scoring systems are different for each assessment. Moreover, several assessment tools involve the collection of information on the individual, such as their goals, needs, abilities, and functional status (including perceptual, cognitive, and physical functionalities). In addition, many of the guidelines

in the literature outline several factors to be considered about the individual in conducting a thorough assessment, including his/her support network, transport considerations, age, and personality (Carden, Elliot, Adderley, & Cook, 2009; EnableNSW, 2011). Other information items often collected in assessments are details about the environment where the PWC will be used, as well as information about the PWC options to be considered. All of these data items are gathered in order to effectively match a unique individual with an appropriate PWC. Overall, there are some quantitative measures which are collected; the person's anthropometric measurements, scoring on mental testing, and wheelchair skills performance scores are examples of numerical measures informing assessment decisions. Nevertheless, much of the information influencing assessments is qualitative, such as a description of the PWC user's goals, environment, and support from caregivers. The vast majority of data informing assessment decisions is also subjective, as it depends on the assessor's judgment of the potential PWC user's environment, needs and abilities, relative to the available PWC technology options. Other factors that might affect decisions around provision include specific provision criteria (e.g., level of functional independence with the PWC) as well as funding policies.

Researchers have attempted to build "smart" wheelchairs for decades. A comprehensive review of earlier smart wheelchair research can be found in (Simpson, 2005). An example of a smart wheelchair can be found in Fig. 1. These technologies consist of sensors and actuators that can collect information on the PWC, the driver, the environment, and the interactions between them, and use this information to modify the behavior of the wheelchair or driver. It is possible that these technologies could be used to develop tools that can optimize the time spent in training, and aid in the assessment of specific aspects of PWC driving, such as safety. However, the use of these technologies by clinicians and drivers in assessment and training is largely unexplored, and was thus the main focus of the Smart Wheelchairs in Assessment and Training (SWAT) initiative involving national and international experts in the field.
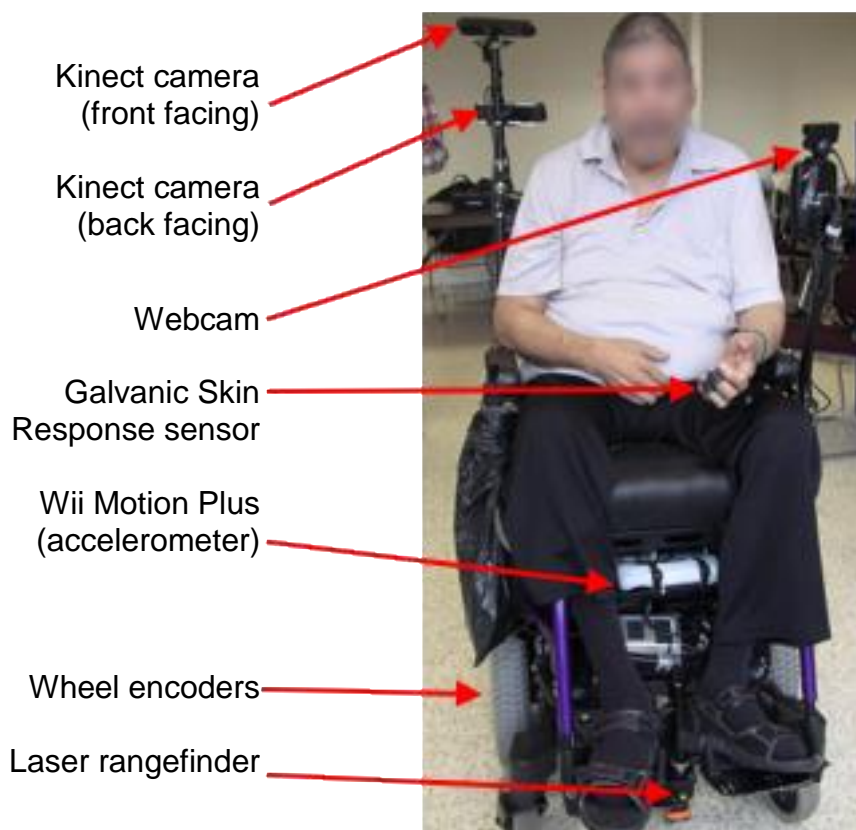

Figure 1. Example of a smart wheelchair.

The main objectives of the SWAT initiative were as follows:

1. *Exchange knowledge of current practices* in assessment and training, and *discuss the gaps in information* that would be useful in decision-support (led by expert clinicians);

2. *Exchange knowledge of the sensor data and intelligent processing* currently offered by smart wheelchairs (led by expert engineers and computer scientists);

3. *Brainstorm applications* of smart wheelchairs in informing and/or augmenting assessment and training processes, and the implications of using this technology from a clinical perspective;

4. *Identify future research directions* in applying state-of-the-art smart wheelchair technology to assessment and training;

5. *Disseminate workshop findings through conferences and/or peer-reviewed publications*; and

6. *Foster international collaboration and initiate development of a research proposal* examining the application of smart wheelchair data in the development of clinical decision-support tools for assessment and training.

The purpose of this state of the field report is to summarize the SWAT initiative involving a literature review; discussions held at a consensus workshop in Toronto, Canada; a member checking survey; a round table meeting; and repeated participant feedback on new versions of the report. The report also provides a description of the workshop process and analysis of the different perspectives used to arrive at high-level recommendations to advance the field.

Methods

The workshop process was guided by the Cornell Institute for Translational Research on Aging (CITRA) Research-Practice Consensus-Workshop Model (Sabir et. al, 2006). Following the stage of selecting and defining the topic, the process includes the following steps: convening an expert panel of researchers and practitioners (advisory group), completing a nontechnical review of the literature (nontechnical literature review), convening researchers and practitioners in a meeting (workshop) to generate an initial consensus statement of recommendations pertinent to research and practice, and conducting a follow-up meeting (teleconference) to create a consensus document. The final stage includes developing a plan for disseminating the outcomes. Some workshop processes and activities diverged from the CITRA model, such as use of a more rigorous literature review process, a longer workshop duration, the inclusion of an expert panel discussion, and the addition of several post-workshop activities to arrive at the final report with recommendations and future directions.

Advisory Group

The advisory group was convened by the primary workshop organizers (P. Viswanathan and R. H. Wang) with membership based on a balance of clinical and technical expertise. Members with clinical expertise were two occupational therapists (R.H. Wang, W.C. Miller) and a physiatrist (R. L. Kirby) with research and practice experience with users of powered mobility and powered mobility assessment and training. Members with technical expertise were two engineers (A. Mihailidis, R.C. Simpson) and a computer scientist (P. Viswanathan) with expertise in technology research and development of smart wheelchairs and with research experience working with powered mobility users. The advisory group, with six members in total, inclusive of the workshop organizers, carried out the role of overseeing the direction of pre-

workshop activities, reviewing drafts of the nontechnical literature review, and planning the workshop agenda activities.

Nontechnical Literature Review

The purpose of the nontechnical literature review was to present an up-to-date summary of the field to function as background reading for the workshop and to stimulate discussion. Two reviews were conducted to develop the final nontechnical literature review. The specific methodological framework for the reviews was informed by Arksey and O'Malley's (2005) stages for conducting a scoping review: 1) outlining the research question(s), 2) gathering literature, 3) selecting the most pertinent studies, 4) extracting the data, and 5) summarizing key findings. A scoping review was conducted focusing on standardized powered wheelchair assessment and training tools, emerging tools and clinical guidelines and best practices. A technical review was conducted and detailed prominent examples of sensors used in smart wheelchairs, as well as technological interventions for powered wheelchair assessment and training. Parts of the second review have been published in (Viswanathan, Simpson, Foley, Sutcliffe, Bell, 2017). Both reviews were led by a workshop lead (P. Viswanathan) and carried out by a research assistant (J. Bell). The nontechnical literature review was presented in language that was intended to be understandable by an interdisciplinary audience.

Workshop

Participant selection

To ensure a rich and diverse discussion on smart wheelchairs applied to assessment and training, invitees were selected based on their prominence in the areas of smart wheelchairs research and/or powered mobility research and practice experience. Other criteria selected for a mix of roles (e.g. research, clinical and technical practice, industry and policy), disciplines (e.g. occupational and physical therapy, nursing, engineering, computer science, rehabilitation or other clinical sciences and sociology) and geographical locations (e.g. North America, Europe, Australia). Participants were from diverse career stages and included several trainees (e.g. graduate students who were primarily from Canada). Of the 38 initial participant invitees, 31 participated[1]. A list of attendees (and their expertise) can be found in Appendix A.

Process and activities

The workshop took place in Toronto, Canada. All sessions were video recorded to accurately capture events and to facilitate post-workshop analysis. All participants completed a consent form for video recording for the stated workshop objectives. The workshop was facilitated by the two primary workshop leads (P. Viswanathan and R. H. Wang), and spanned over one and a half days. Small and large group discussions as well as a panel discussion were conducted. Small group discussions to address the workshop goals examined the following topics: 1. Current practices in assessment and training, and information that would be useful in decision-support, 2. Sensor data and intelligent processing currently offered by smart wheelchairs, and 3. Applications of smart wheelchairs in informing and/or augmenting assessment and training processes. Following small group discussions, workshop attendees reconvened as a large group to summarize each groups' discussions. The second day started with a reflection of the previous day's discussions, a question and answer panel discussion that involved clinical and industry stakeholders, and a presentation by Dr. François Michaud on the "Valley of Death", i.e.,

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[1] The wheelchair controller manufacturer only attended the panel discussion via Skype video conferencing. Seven experts, including a policy maker, were interesting in participating, but were unable to attend the workshop.

the gap between basic research and commercialization of technology (https://cfs.nrcan.gc.ca/selective-cuttings/51) (slide contributed by Dr. Luc Fréchette). In the final session of the workshop, participants collaborated to identify next steps and deliberate consensus statements. All workshop discussions were documented through notes made by a) the individual groups during small group discussions though shared online documents, b) a designated organizer during large group discussions, and c) the workshop leads in a review of the video recorded large group discussions. An overview of the agenda can be found in Appendix B.

Workshop follow-up activities and analysis

All of the notes based on the workshop discussion sessions were summarized by the workshop leads. The summary, which included all of the workshop findings, was sent to the participants by email for review (as a form of member checking and to capture reflections and feedback after the workshop). The email also included a brief post-workshop reflection survey that asked participants to identify key insights on current practice, challenges to be addressed, and their recommendations for future work. Responses (a total of 18) were received within three months after the workshop.

Analysis of the summary with participant comments and the survey data was carried out by an interdisciplinary group of authors to generate a "state of the field" report over the next five months. The author group included clinical (R. H. Wang, L. Kenyon) and technical researchers (P. Viswanathan, A. Sutcliffe, G. Foley). Because workshop discussions occasionally diverged to assistive technology in general or to mobility technologies other than powered wheelchairs, it was determined in advance that the analysis exclude this content and focus on smart wheelchairs. Each author was allocated a topic area (based on the workshop objectives and discussion topics) to thematically summarize into the report using the summary document along with the received participant comments and survey results. Original notes from the workshop discussions were also reviewed for clarification as needed during report writing. All authors contributed to writing the final section of the report with consensus statements and recommendations. A shared online document was created to facilitate report writing such that all sections were available for the other authors to view, thus expediting reviews and resolution of queries in report content and interpretation of the findings during the summarization process. All authors involved in the report writing reviewed the full draft to ensure coherency and consistency in the report.

Teleconference

The "state of the field report" was then circulated, and a two-hour roundtable conference call was convened to discuss any feedback, review and refine consensus statements, recommendations, and future work and dissemination approaches. Twenty-two workshop participants were in attendance. Following the discussion, the report was updated and then circulated to all workshop participants and collaborators for their final comments. Any additional comments were integrated as appropriate.

SWAT Initiative Findings

Key findings from the workshop discussions and comments/feedback collected post-workshop were clustered in three areas: challenges in assessment and training current practices, potential technology solutions, and challenges in development and deployment. Consensus statements and research questions from the final workshop discussion are also provided along with recommendations for future work. Of note, these findings are based on the experiences and opinions of the workshop participants.

Challenges in Assessment and Training - Current Practices

Several challenges were identified regarding current clinical practice. These can be grouped into three main themes: 1) roles and goals of powered mobility, 2) variability in clinicians, clients, and processes, and 3) barriers and restrictions to powered mobility access.

1) Roles and goals of powered mobility

Discussions highlighted that the roles and goals of powered mobility training and use may be expanded. There is a continuum of ways in which powered mobility may be beneficial, ranging from exploration, learning and development (i.e. remediation type goals) to independent use for daily mobility needs (i.e. compensatory type goals to e.g. help get from point A to B in the community in spite of mobility restrictions). Current clinical practices for assessment and training aim to enable safe and independent mobility using PWCs, and neglect other potential opportunities that powered mobility may offer in the learning process itself. For example, one participant stated that for children, powered mobility skills (e.g. navigating through corridors, parking at a table) were not taught directly. The environment was set up to engage the child, and exploration and mobility using the PWC was encouraged. In this application, powered mobility is a clinical tool to support learning. A significant clinical challenge lies in overcoming barriers (e.g. differences in clinical perspectives, need for evidence of benefits, and restrictions on resource allocations) to enable use of powered mobility for purposes other than enabling independent mobility.

2) Variability in clients, clinicians, and processes

Clients

Participants identified that clients (the users of the powered mobility devices) were not included in the consensus workshop and that their perspectives could make important contributions to the discussions. Client perspectives were acknowledged to be potentially different for different clients and from their caregivers or others.

Many challenges experienced by clients were reported by participants (clinicians) and included personal factors (e.g. decreased confidence, feelings of self-efficacy, self-reported desire to use technology, perceptual problems, ability to learn, social determinants of health – income, gender, culture) and environmental conditions (e.g. built and natural environments, social stigma related to disability). Related to use of powered mobility, abilities and skills such as learning cause and effect (e.g. for children) and learning to move/control the environment in addition to driving around obstacles, cluttered or small spaces, and in crowds were concerns. Challenges were also identified regarding the social issues related to the uptake and use of these technologies, including ongoing social stigma related to disability in general and the acceptability of risk and who determines acceptable levels of risk.

It was discussed that all clients are different and that customization of clinical approaches and technologies is critical. Of importance are understanding clients' goals/needs, abilities/skills, preferences, motivations and environments in order to customize solutions. Remaining flexible to clinical demands and approaches is also important. Ongoing clinical challenges include understanding client factors, and knowing how to best match clients and technology (or match technology to the client).

The potential value of smart wheelchairs was reinforced for some workshop participants, as something that is essential to making the lives of people with mobility impairments easier (e.g. go to places faster and with less physical demand for them) and more independent. Benefits of

the technology can thus include increased overall quality of life as well as decreased caregiver strain.

Clinicians

Clinicians were reported to be extremely busy (e.g. high caseloads) and as such they have limited time, funds, and energy to spend with individual clients. Differences were noted between clinicians in the way they assess and train clients, and these differences related to personal preferences and strategies applied. There was substantial variability reported regarding clinicians' attitudes toward and knowledge of new technologies. Participants observed that while some clinicians are very supportive of new technologies, others might first require a demonstration of acceptable levels of safety, as well as clear value added to the client and/or clinician. It was stated that clinicians are often unaware of current technologies and might not have sufficient time to learn new technologies, thus tending to rely on older technologies with which they are familiar. The reported adoption of new technologies presented by researchers was anecdotally found to be typically low.

Challenges identified by participants related to the importance of gaining "buy-in" for new approaches from a broader spectrum of clinicians. With respect to smart wheelchair technology, a further challenge relates to persuading clinicians that the use of these technologies for assessment and training may add substantial value to clients and clinicians (e.g. the development of a "killer" application that can demonstrate clear value would be needed).

Processes

The current clinical processes for assessment and training are highly variable, and in part reflective of the variations in clinicians and the need to customize approaches and solutions for clients and their unique situations. In current practice, the process of assessment is often used to determine if the client is eligible (in terms of safe and independent use) for prescription of a powered wheelchair, and the function of training is to improve underdeveloped capabilities that limit prescription of a powered wheelchair. Assessment and training are not standardized and there are differences in how clients are trained. In most clinical scenarios training and assessment are not clearly distinct and happen simultaneously. Clinician support during the assessment and training process was described to be very interactive and responsive to clients' needs and instructions often need to be very well explained. Staff availability and time constraints often limit opportunities that clients have for training. Training time was also dependent on clients' abilities and other factors such as their access mode (e.g., joystick, head array, Sip-and-Puff, etc.) to control the powered wheelchair. A common strategy identified was to have the client sit in a PWC and try driving it in order to determine the potential to use it. It was noted by some clinicians that part of the ongoing learning process was enabling clients to make mistakes and learn from them, however, the comfort level for "letting go" was variable between clinicians, family members and institutional policies. Clinicians are also only able to see a "snapshot" of clients' driving during their time with clients and thus do not have a complete picture of their performance over time and in different environments (e.g. including situations of decline with neurodegenerative conditions, or occurrences of accidents or near misses reported by caregivers or others). Geographical variations across different institutions, states/provinces, countries, and continents were also identified in who carried out the training (e.g. clinician, vendor or rehab assistant) and in the abilities that need to be demonstrated in order to be eligible for training.

There is a reported lack of use of formal training and/or assessment programs, which may lead to inconsistencies and variable records of results. With respect to standardized assessment and training tools, clinicians tend not to use them. Several reasons were suggested: labour intensive, require too much setup, specific tools do not cover all necessary aspects, and lack of

incentive for clinicians to collect data (e.g. outcome measures for insurance companies). Information technologies, e.g. that document personal and performance data, are not commonly used. Technologies that are added on to wheelchairs (e.g. data loggers tracking distances, locations) can be difficult and time-consuming to set up. Decisions rely on clinicians' experiences/clinical reasoning/judgement to determine if a client can be prescribed powered mobility or to determine the duration for assessment/training prior to denying or prescribing a powered chair. The issue of some clinicians' inappropriate use of assessment tools to determine who can/cannot or should/should not use a PWC was raised. It was also stressed that there was no substitute for clinical experience/reasoning, but that new approaches and tools may augment or improve current practices.

Some of the ongoing clinical challenges noted in the assessment and training for powered mobility, many of which warrant further discussion and research, included the following:

1. Identifying the best practices for the assessment and training process (including how to account for variations in clients' skill/abilities/confidence, and the need to customize the technology and training);
2. Developing better behavioural/observational/functional cognitive assessments that can monitor change over time and that do not rely on pencil and paper tests;
3. Improving trials to represent variable real-world situations (e.g. weather conditions such as rain, inclines that are not standard) and progressing from simple to more difficult/complex environments;
4. Determining the most efficient/expedient practice for assessment and training, how to decrease training time (and achieve independent mobility faster);
5. Determining when to stop training and consider compensation;
6. Examining criteria to determine when a client has achieved safe/acceptable levels of skill in use of a mobility aid;
7. Improving safety and comfort of PWCs, and the usability of PWCs and training programs;
8. Determining methods of long term follow-up and review to ensure clients maintain skill levels and to see if they have encountered challenges which require further investigation or training;
9. Accommodating changes in abilities and use of powered mobility (e.g. with cognitive or neurodegenerative changes, and delays in getting technology resulting in changes in abilities).

3) Barriers and restrictions to accessing powered mobility

It was stated that people who might benefit from currently-available PWCs and other technologies are excluded from access. The most significant barriers are the high cost of equipment and funding constraints (funding models and economics of provision). Further exclusion from access results from current provision practices (e.g. availability of training and supervision), limitations in commercially-available technology to accommodate client needs, and restrictions to use owing to safety concerns (e.g. some long-term care facilities restrict powered wheelchair use to minimize the risk for accidental injuries).

It was reported that it is difficult to make an economic argument for smart wheelchairs (e.g. in terms of numbers of users, anticipated benefits, and the costs of development, manufacture, and provision). The counter argument raised is that access to powered mobility devices for safe and independent mobility is a basic human right that should be pursued (e.g. the UsersFirst advocacy group in the USA is collecting cases to strengthen the argument).

Challenges regarding access to powered mobility technology included the need to develop better and different funding options and models, to be advocates ourselves to lobby policymakers, and to encourage and develop better methods of consumer (including carer)

engagement in advocacy. A further challenge is locating client advocates as many of them are amongst the most vulnerable client groups.

Potential Technology Solutions

Participants agreed that smart wheelchairs and their data have the potential to assist with powered mobility assessment and training. Different sensors/technology can be used to assist assessment and training and address clinical needs. Smart wheelchair technology may be used to train more clients and for longer periods of time by allowing unsupervised training while ensuring client safety. This may allow more users to benefit from powered mobility by becoming eligible (for either a conventional powered wheelchair or a smart wheelchair) through extended and potentially new training strategies.

In addition to the new capabilities available through smart wheelchairs, a variety of data may be collected while the client is using the powered wheelchair (e.g. during driving trials or long term use) and these data (and the developed tools) are thought to serve multiple purposes to augment clinical practices:

1. Identifying individuals with potential to learn how to drive a powered wheelchair and to allocate resources accordingly;
2. Identifying navigation aspects that require further training as well as strategies that can improve driving performance;
3. Creating objective performance measures based on meaningful and clinically valid information extracted from smart wheelchair data;
4. Ongoing and long-term monitoring of drivers in real-world environments in order to identify issues outside of the clinic, to anticipate and detect changes in driving ability, and to prevent accidents;
5. Using performance assessment and the extent to or manner in which smart wheelchair data/tools are used in order to verify intervention outcomes.

Participants with experience in the provision of PWCs were clear that technological tools and data should be used to inform decision making (e.g. in a decision whether or not to prescribe a PWC) rather than to direct it. Data could be used to supplement the clinical tools (e.g. assessment tools, clinical observation) currently used to inform clinical judgement.

Different types of applications were identified that could be used to implement some of the above functions. These applications fell into two categories: 1) assessment and monitoring or 2) assisted mobility.

1) Assessment and monitoring

Traditionally, clients and clinicians interact directly with each other or with the PWC device. With the proliferation of portable computing found in mobile devices such as smartphones and tablets as well as the availability of inexpensive and reliable sensors, new pathways of communication are opening up between clinicians, clients, and their assistive technology. These pathways allows for better performance assessment and long term monitoring. Focused data can now be gathered through extended periods of wheelchair activity with the help of (but not limited to) proximity sensors for obstacle detection, pressure plates to measure weight distribution, cameras, GPS and Wi-Fi for location and driver identification, and biometric sensors and cameras for driver state assessment. The ability to monitor clients would help optimize training periods and improve assessment without increasing clinician burden. Research into assessment and monitoring could help to better understand powered mobility and create opportunities for concrete improvements in the quality of life of clients. In addition, further investigation into

telepresence applications and transferability of PWC skills learned in virtual reality simulations to real life environments are recommended.

The development of new modalities for the assessment and monitoring of PWC users requires a human computer interaction approach. Several sensors for assessment and monitoring have already been developed (proximity sensors, GPS, etc.); however, the focus needs to be shifted to adapting these technologies. Any successful research group in this field will have to tackle important user-centered design challenges, including establishing processes to engage end-users in the design process, and creating interfaces with high usability that accommodate for varying user needs and abilities.

Ideas about potential technologies for assessment and monitoring were presented. Most were considered to be "low hanging fruit" from a technology perspective, meaning that engineers currently have the technical know-how to develop these ideas. Due to the time constraints of the workshop, no consensus could be reached as to specifics regarding these technologies. While this was in large part due to the many challenges presented in the following section, one stood out in particular: the sparsity of challenging engineering research questions. Clinical research questions, however, were numerous, although they may not be the ones that are most pressing to address immediate clinician or client needs.

Engineering research questions
- How can rich and large amounts of sensor data be presented to the user, caregiver, and/or clinician in a concise, meaningful, and useful manner?
- How can sensor data (including video) be gathered and processed in a manner that respects the privacy of the user and others in the environment?

Clinical research questions
- How can video and sensor data augment real-time clinical observation?
- How can sensor data (proximity data, driving behaviors, localization and mapping information, users' weight distribution over different wheelchair parts, etc.) be presented in order to convey meaningful information regarding user health, safety, activity, participation, etc. at any point in time? How can these data be seamlessly integrated into clinical practice? How can these data be used to identify changes over time?
- How can anonymized real-world data of powered wheelchair use add value to clinicians and clinical researchers?
- What are the concerns with regards to security and ethics when collecting the above data and potentially using the data in decisions related to training and assessment?
- Does a tele-health system improve uptake of wheelchair technologies in rural or remote areas without access to a qualified PWC trainer?
- What attitudes do the key stakeholders (e.g., the user, caregiver, and clinician) have toward smart wheelchair technology?

2) Assisted mobility

Whether it be direct feedback through a PWC joystick or fully autonomous navigation, assisted mobility is a field rife with technical challenges. This field is concerned with any technology which can interpret its environment along with driver commands and output a recommendation or an action. Typically this encompasses ideas such as shared control via compliance actuators and intelligent algorithms, or even further automation of specific tasks such as docking at a table or high level commands such as planning and executing a path between two points on a map. More broadly participants in the workshop brought up the possibility of developing training opportunities using a wide variety of tools, whether it be smart devices such as hand held tablets or companion robots which a driver must follow.

In the case of assisted mobility, ideas put forth were much more ambitious from a technological point of view. For this reason, engagement from engineers was higher, but clinical impact was much less clear. Research questions were numerous on the engineering side and limited on the clinical side due to the lack of maturity of the technologies proposed.

Engineering research questions
- How should shared control be implemented?
- How and when should the type and level of control be modified? How should this level and type of control be communicated to the user (i.e., how should a feedback system be implemented?)
- How should an override feature be implemented?
- How should a reliable and safe navigation system be developed?
- How should a wheelchair intelligently navigate in crowded areas?
- How and when should a smart wheelchair avoid obstacles?
- How and when should multiple smart wheelchairs coordinate their actions in, for example, an assisted living environment?
- What other control interfaces could be used (brain control interface, tongue drive)?
- How can smart wheelchair technology benefit from artificial intelligence to provide user and environment adapted feedback and navigation?

Clinical research questions
- How/when should smart wheelchairs be used for remediation and/or compensation?
- How can feedback be provided to users such that it is acceptable to them, while helping to meet clinical goals?
- How can shared control be implemented such that it is acceptable to users, while helping to meet clinical goals?

In general, the engineering research questions focused more on implementation techniques, while the clinical research questions focused on usability and integration with clinical practice. Ultimately, an interdisciplinary approach will be necessary in order to create tools that are effective, usable, and add value to all key stakeholders.

Challenges in Development and Deployment

Many challenges, technical and clinical, were identified in developing and deploying the above applications of smart wheelchairs and their data. Further discussion, research, and development will be required to ensure the use of smart wheelchair data and tools in clinical practice.

Clinical challenges

Many of the challenges to be addressed relate to finding ways of preprocessing or reducing and interpreting the data from a potentially large volume of information from driving sessions or day to day use. The data provided by the newly developed assessments and tools must be presented/provided in a way that is brief, easy for clinicians to understand and provides practical information. Ideally, the information provided can be used to guide decision-making/practice or enable advocacy for clients' needs. Solutions would need to offer valuable clues and insights without increasing the workload for clinicians. Examples may include identifying a minimum data set to determine clients' skill levels, having a standard evaluation metric that is used by everyone (this will help push development, but is hard to do because of diversity of potential users), and producing metrics that can be related to broader outcomes regarding function, health and wellbeing.

Technical challenges

Issues and challenges pertaining to the development of new technologies in this field were focused on the need for user-centered and clinically relevant design while simultaneously considering client health and safety in a way that opens up interesting engineering challenges.

Given the diversity of the potential user base, human factors and human robot interaction research should take a central role in any complete research project. Desired functionality and behaviors, improvements over current technologies, types and content of feedback, level of driver control, ability to override the system, acceptance and attitude towards the technology are examples of questions that should be investigated and which relate directly to the interface between clients and technology. For example, with assisted mobility, determining the level of assistance to be provided is crucial in ensuring safe operation while maintaining client abilities. For any given level of assistance, seamless interactions are a requirement that can only consistently be met through extensive and rigorous user testing. Unfortunately, access to potential clients and clinicians is very limited, and comprehensive well-designed studies require sufficient funding and time, thus posing additional challenges to research and development.

A major challenge identified during the workshop is the integration of intelligent features with commercially available wheelchairs since their controllers are closed, proprietary systems. Systems that do not require motor control must also be well designed to ensure compatibility with wheelchair hardware and form factor as well as be quickly and easily retrofitted onto the wheelchair. Some clinicians reported not wanting to use an add-on system provided by engineering colleagues because the encoders necessary for the system to work were too time consuming to install. Improved collaborations between and amongst researchers are needed in order to better use resources and prevent the duplication of work (e.g. identifying common technologies being developed for different client populations).

Cost

Even with properly designed technology, access to technology was a key problem reported by clinicians and explained by a combination of factors. The cost of the technology can be a huge barrier, preventing systems developed in research from making it into the hands of the users. For example, while a $50 add-on solution suggested in a small group discussion by an engineer in industry seemed low-cost to develop according to the researchers in the group, the clinician found the cost too high to warrant trialing or adopting the new technology. While technology can be introduced into clinical practice from the research lab at a low scale, access remains limited until production can be scaled for larger demand. It was argued that wheelchair manufacturing companies would only be interested in producing new products if the demand is considerable in size, i.e. upwards of 10,000 units, which may be unrealistic for some of the applications enumerated above where the market size is expected to be more limited.

Ethics and safety challenges

Further hurdles to development in power mobility technology are safety and ethics. Safety is a critical element in the provision of PWCs and any technology that has the capability of moving the wheelchair without driver input must also be thoroughly assessed to ensure client safety. Some potential risks in assisted mobility technologies are associated with sensor robustness in different and changing environments (e.g., low accuracy of many sensors in certain lighting conditions, decreased reliability of wireless communication). Privacy and security issues become concerns with the use of cameras or physiological monitoring which can record sensitive information. While the necessary precautions can be taken to protect the client as with any other sensitive medical information, research and development efforts should focus on minimizing potential privacy issues. An important ethical issue raised by the development and use of monitoring technologies is its use in deciding to take away an individual's wheelchair. As previously stated, monitoring data cannot and should not be used for decision-making, but

should be used as one tool among others that inform clinicians' decisions. Clients must be aware and consent to logging of any information in their day-to-day use of the technology. In addition, strategies or new technologies to overcome sensor robustness issues must also be developed to ensure client safety.

Stakeholder collaboration

Collaboration between clinicians, researchers, and entrepreneurs / inventors was identified to be valuable and needed to be strengthened. It was acknowledged that some stakeholder perspectives were absent or limited in the current discussion: clients, hospital administration, insurance companies, funding agencies, charities, and community groups. Increased representation from industry was also identified as a need. These expanded collaborations may assist with transfer and uptake of knowledge and technology from the lab to the clinic, as well as moving innovations into general practice or to commercial availability.

Throughout the workshop, the conflicting needs and objectives of the various stakeholders in attendance emerged as "tensions" within the group as a whole. Tensions or conflicts between academia and industry, engineers and clinicians, engineering researchers and non-researching (industry) engineers, and clinical researchers and non-researching clinicians were identified as outlined below in Figure 2. Identified tensions between academic researchers and industry appeared to relate to the often contradictory agendas in each arena. Key tensions between these stakeholder groups included: the demands of power mobility and technology research versus the demands of product development, the need for funding to validate products and technology versus the need for product validation before being able to obtain funding, and the complexity of moving forward an idea from the sometimes idealistic and altruistic academic setting through the commercialization process and into the market-driven world of industry. Tensions between engineers and clinicians included technology limitations versus user needs, the clinical applicability of technology versus the technological capacity of a device, and concerns related to product cost and ease of use. Tension between researchers in engineering and clinical fields appeared to relate to the fundamental differences between research questions in the two different professions and the possibility of divergent research questions centered on the same technology.

	Engineering World	Clinical World
Academia	Engineering Researchers	Clinical Researchers
Industry	Engineers	Clinicians

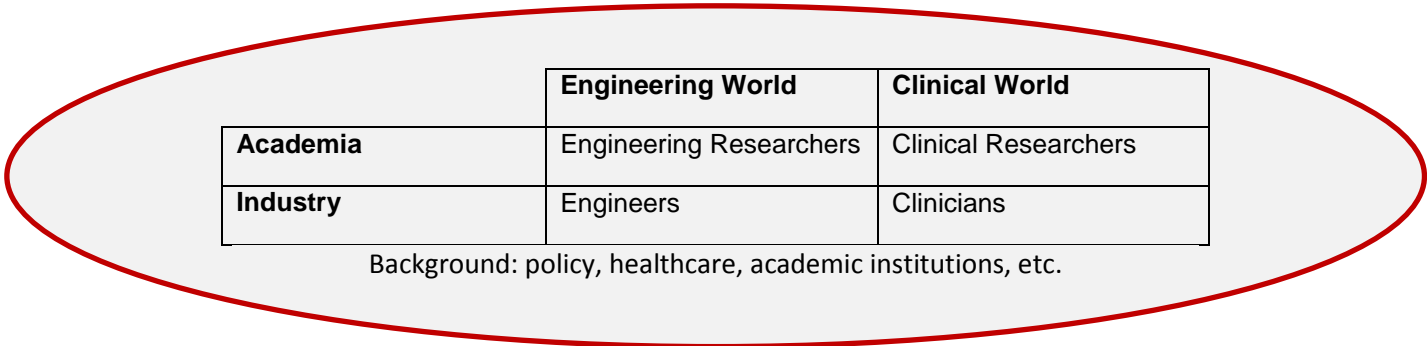Background: policy, healthcare, academic institutions, etc.

Figure 2. Tensions

Perhaps the greatest identified potential for tension between stakeholder groups centered on communication and professional language barriers between engineers and clinicians. A common language with clearly defined terms and a willingness on the part of both professions to move out of their discipline-specific silos were identified as ways to avoid a phenomena labeled as "Lost in Translation" in which ideas and concepts were lost due to communication barriers between the two professions. Despite these communication issues, however, attendees consistently expressed a desire to improve relationships between the two groups. Respect for

the various agendas and needs of the different groups was often coupled with a willingness to compromise and cooperate in an effort to help bring forth products for patient use.

Commercialization challenges

The timeline and process of bringing a product from an idea through to commercialization for general patient use were identified as a challenge faced in bringing forth new technologies. As depicted in Figure 3, the process of bringing new technologies into the market typically starts with an idea that must be developed and refined through designing and testing various prototypes in order to establish the efficacy of the technology. To move through this process and result in a product ready for the market, an idea must capture the interests of multiple stakeholders, all of whom may be driven by different needs and desired outcomes. For example, clinicians often want a product that not only fills an identified patient need but that is easy to use and relatively low cost whereas stakeholders in industry may be most interested in products for which there is a recognized and plentiful market. Most researchers also felt that they were not necessarily comfortable or interested in having an active role in knowledge translation and/or the commercialization of products. Yet without an expert to move the product through to the market phase, many products may not become available to clinicians and/or clients. The length of time often required to bring a product to market may result in technologies becoming obsolete before products actually reach the market. Such tensions were often thought to result in a breakdown in the development and deployment timeline. The time period between the completion of pilot trials and the development of a high-fidelity prototype was identified as a particularly vulnerable point in the process. At this point the engineering research challenges have already been addressed, development costs are high but funding and resources are scarce at this point in the process, and other issues such as market size and intellectual property rights come into play. The current trend of research funding agencies to favor local industry partners can be detrimental when there is no local industry (e.g. few Canadian wheelchair manufacturers). In addition, further challenges are faced in gathering the clinical evidence necessary for deployment. While randomized controlled trials are considered the gold standard in clinical studies, these are difficult to conduct for many assistive technology interventions and populations (e.g., challenges in recruitment, scheduling, seating, cost, etc.), and study findings might have limited generalizability in practice.
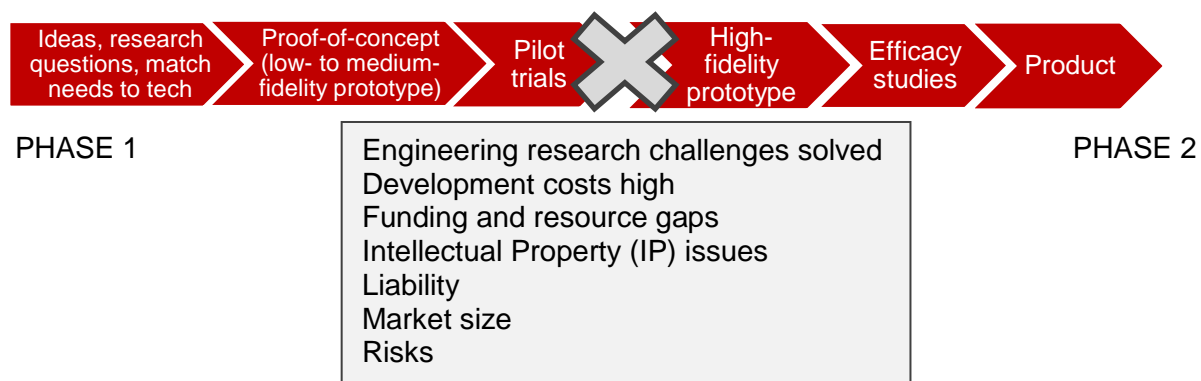

Figure 3: Development/Deployment Timeline

Consensus Statements and Research Questions

The SWAT workshop led to the following high-level consensus statements during the final session:
- Assessment and training is context dependent
- Smart technology has a role in assessment and training; it can lead to the inclusion of more people who are currently excluded

- Smart wheelchair applications go beyond assessment and training
- Policy issues regarding access need to be addressed
- Therapeutic use of smart wheelchairs is important
- Knowledge translation is required to educate clinicians about the possibilities of technologies, and to educate researchers about challenges in clinical implementation of assistive technologies
- There is a range of "smartness" in wheelchairs; the system can be a modular, multi-modal, multi-functional platform
- Shared /collaborative control is an important part of training but the method to implement/apply it is unclear
- Data sharing is necessary to help move the state of the art forward
- Alternative approaches to evaluating technology must be explored beyond RCTs (e.g., mixed methods research)
- Short-term goals (low-hanging fruit) need to be balanced with longer-term goals (pie-in the-sky ideas)

The following research questions were prioritized for future investigation:
- What is the optimal (e.g., most efficient) way to train someone (e.g. haptics, VR, shared control, etc.)? Which subgroups might these protocols benefit most? What works for who and how?
- What are standardized outcomes to measure training?
- How can sensor data help assessment? How should data be summarized in a clinically meaningful manner? What is "good" performance (context-specific)? How can we prevent unduly exclusion (therapist underestimation and driver overestimation of wheelchair skills)?
- What are important criteria for assessment and training tools?
- How should data-sharing protocols be implemented?

Recommendations

The high-level consensus statements and research questions listed above summarize the current state of the field and identify areas that should be explored in the future. While we were unable to reach consensus regarding specific applications or functions that should become the primary focus, we were able to identify sets of predominant interest amongst the participants. Four different interests were revealed: engineering research interest, clinical research interest, cost and clinical impact. These interests correspond to the four main groups of people that were present, engineers/computer scientists, occupational/physical therapy and nursing researchers, industry and clinicians respectively. Evaluating research ideas based on the challenges they pose and the relevance they have in each of these four areas could help have a more open and honest discussion about shared interests, motivations, responsibilities, and the potential for collaboration among smaller groups. Furthermore, in order to speed up development efforts and avoiding duplicating efforts, barriers to sharing data arising from university policies and incompatible formats must be overcome. Anonymized methods of collecting and sharing data must be implemented to allow data sharing while protecting the privacy of study participants.

Partnerships with manufacturers might lead to standardized interfaces that can easily access information currently being discarded by PWC controllers (e.g., joystick movements, speed settings, etc.). Collaborative research between clinicians and engineers is also required to determine what constitutes clinically meaningful data and how it should be presented to be useful and to increase clinical uptake. Once these systems have been developed, further research could delve into the implications of the use of the technology in terms of how monitoring complements or compares to real-time clinical observations, how they assist clinicians in improving care by providing outcome measures and providing supplementary information towards decision-making, as well as how they affect clinical workload. In addition, the use of PWCs as a clinical and/or recreational tool to encourage exploration and learning

should also be considered and investigated.

Alternative methods for evaluation, such as Campbell's framework for complex interventions (Campbell et al. 2000) should be investigated. In this framework, a phased approach to development and testing is recommended in order to help researchers clearly define what stage of the research process they are in. The use of mixed-methods research (quantitative and qualitative methods) are also recommended in order to improve generalizability and validity of results.

Despite the identified tensions, throughout the initiative, each participant expressed a desire to work together to improve and reconfigure both the timeline and the process for bringing technology into the market for client use. Suggestions related to this reconfiguration centered on strengthening collaborations to better understand clinical needs, improving communication between stakeholders through the creation of a common language and cross-disciplinary training, investigating alternative funding sources such as partnerships between researchers and industries, better ways to package and market the technology, and ways to help clinicians and patients to see the value of technology. The above suggestions could potentially help decrease the amount of time it takes to bring a product to market. Case studies of the participants' experiences relating to interdisciplinary research, knowledge translation, and commercialization of assistive technologies are currently being documented to help inform future guidelines.

Conclusions

Successful deployment of smart wheelchair (and other assistive) technologies requires buy-in from various stakeholders, including end-users, therapists, researchers, developers, and policy makers. Strong collaborations, knowledge translation, and knowledge mobilization are thus essential in ensuring buy-in and adoption. The interdisciplinary SWAT initiative highlighted both tensions between stakeholders that need to be addressed, as well as the group's consensus on research and development priorities. The development of new data sharing protocols and alternative methods for technology evaluation were suggested in order to reduce barriers and speed up development and deployment of assistive technologies. Finally, several suggestions for simpler applications were identified in this document, which should be balanced with some of the longer-term research questions posed, in order to move the technology forward while solving some of the current challenges faced by clinicians and their clients in powered wheelchair assessment and training.

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Appendix A: Workshop Attendees

Name	Title	Expertise	Affiliation
Alex Mihailidis*	Associate Professor	Rehab Engineering	Dept. of OS/OT & Institute of Biomaterials and Biomedical Engineering, University of Toronto, Toronto Rehabilitation Institute (TRI), ON (Canada)
Andrew Sutcliffe	Masters Student	Computer Science	Reasoning & Learning Laboratory, Dept. of Computer Science, McGill University, Quebec (Canada)
Ben Mortenson	Assistant Professor	OT	Dept. of OS/OT, University of British Columbia (Canada)
Bill Miller*	Professor	OT	Dept. of OS/OT, University of British Columbia (Canada)
Christian Mandel	Senior Researcher	Rehab Engineering /Computer Science	German Research Center for Artificial Intelligence, Germany
Daniel Zondervan	Co-Founder	Rehab Engineering	Flint Rehabilitation Devices (U.S.)
Ed Giesbrecht	Assistant Professor	OT	Dept. of OT, University of Manitoba (Canada)
Emma Smith	PhD Student	OT	Dept. of OS/OT, University of British Columbia (Canada)
Francois Michaud	Professor	Rehab Engineering	Dept. of Electrical and Computer Engineering, Sherbrooke University (Canada)
Genevieve Foley	Masters Student	Rehab Engineering	Institute of Biomaterials and Biomedical Engineering, University of Toronto (Canada)
Ian Mitchell	Associate Professor	Computer Science	Dept. of Comp. Sci., University of British Columbia (Canada)
Joelle Pineau	Associate Professor	Computer Science	Dept. of Comp. Sci., McGill University, Quebec (Canada)
Julie Blain	PhD Student	Nursing	Dept. of Nursing, University of Toronto
Karen Hall	Clinical Manager	OT	Assistive Technology Clinic, Toronto, ON (Canada)
Kathy McGilton	Associate Professor	Nursing	Faculty of Nursing, University of Toronto, TRI (Canada)
Lisa Kenyon	Assistant Professor	PT	State University, Michigan (U.S.)
Lisbeth Nilsson	OT Researcher	OT	Dept. of Health Sciences (Division of OT), Lund University, Sweden
Lee Kirby*	Professor	Physiatry/ Rehab Research	Dept. of Medicine (Division of Physical Medicine & Rehab), Dalhousie University, Nova Scotia (Canada)
Mark Bresler	Assistive Technology Specialist	Rehab Engineering	Woods Services Inc., Pennsylvania (U.S.)
Marlene Adams	Occupational Therapist	OT	Toronto Rehabilitation Institute, ON (Canada)
Paula Gardner	Affiliate Scientist; Assistant	Social Sciences	Bridgepoint Collaboratory Research and Innovation; Brock University, ON (Canada)

	Professor		
Pearl Gryfe	Clinical and Managing Director	OT	Assistive Technology Clinic, Toronto, ON (Canada)
Philippe Archambault	Associate Professor	Rehab Engineering/ OT	School of PT/OT, McGill University, Quebec (Canada)
Pooja Viswanathan*	Post-doctoral Fellow	Computer Science/ Rehab Engineering	Dept. of OS/OT, University of Toronto, TRI (Canada)
Rich Simpson*	Associate Professor	Rehab Engineering	Dept. of Rehab Science & Technology, University of Pittsburgh, Pennsylvania (U.S.)
Rosalie Wang*	Assistant Professor	OT	Dept. of OS/OT, University of Toronto, TRI (Canada)
Ross Black	Occupational Therapist	OT	Dept. of OT, Prince of Wales Hospital, Australia
Simona Cotarla	Rehab Sales Representative	Rehab Equipment Sales	Shoppers Home Health Care (Canada)
Yiannis Demiris	Associate Professor	Rehab Engineering	Dept. of Electrical and Electronic Engineering, Imperial College, UK
Tom Carlson	Assistant Professor	Rehab Engineering	Aspire Centre for Rehabilitation Engineering and Assistive Technology, University College London, UK
Francois Routhier	Associate Professor	Rehab Engineering	Laval University (Canada)

*Advisory group members

Appendix B: Workshop Agenda

October 6, 2014 (Room 132, 500 University Avenue)	
8:30 – 9:00	Welcome
9:00 – 9:30	Introduction of advisory group, panel of experts
9:30 – 10:00	Overview of SWAT initiative (goals and objectives)
10:00 – 10:30	Scoping review – summary and Q & A
10:30 – 10:45	Break
10:45 – 11:15	Brainstorming Session 1: current practices in assessment and training, and information that would be useful in decision-support (at least 1 clinician per group)
11:15 – 11:30	Report back to whole group for discussion
11:30 – 12:00	Brainstorming Session 2: sensor data and intelligent processing currently offered by smart wheelchairs (at least 1 technology developer per group)
12:00 – 12:15	Report back to whole group for discussion
12:15 – 1:15	Lunch break
1:15 – 2:00	Discussion of findings from previous sessions and review of SWAT goals
2:00 – 2:30	Brainstorming Session 3: applications of smart wheelchairs in informing and/or augmenting assessment and training processes
2:30 – 3:00	Report back to whole group for discussion
3:00 – 3:15	Break
3:30 – 5:00	Discussion of findings, summary of day
Action Item	Workshop facilitators to analyze findings from day 1

October 7, 2014 (Room 132, 500 University Avenue)	
9:00 – 11:30	Discussion of findings from previous sessions ('Tensions')
11:30 – 12:30	Q&A panel with stakeholders
12:30 – 1:00	Continued discussion and presentation of the 'Valley of Death'
1:00 – 1:30	Consensus statements, research questions, next steps (possible grants/proposals/collaborations)
1:30 – 1:45	Highlights and closing remarks