POWERED WHEELCHAIR SKILLS TRAINING FOR OLDER ADULTS WITH COGNITIVE IMPAIRMENT: USING SHARED CONTROL TO FACILITATE INDEPENDENCE

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(Rehabilitation Sciences)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

May 2019

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Powered wheelchair skills training for older adults with cognitive impairment: using shared control to facilitate independence

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the degree of Doctor of Philosophy

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Abstract

Powered wheelchairs (PWCs) promote participation and well-being for individuals with limited mobility. However, many individuals who would benefit from a PWC do not have access to one. This is particularly true for older adults with cognitive limitations who are perceived as being unable to learn or require additional training to become safe and effective drivers. Novel training approaches which address the needs of this population, while maintaining safety in the training environment, are necessary.

Purpose: To generate knowledge through end-user input to develop a wheelchair skills training program for older adults with cognitive impairment, using an errorless learning approach, and evaluate the feasibility of implementing this program in a randomized controlled trial for individuals living in residential care.

Methods: To address the purpose, we conducted three studies: A North American survey of PWC skills training providers; qualitative interviews; a think-aloud task analysis; and a mixed-methods feasibility 2x2 factorial randomized controlled trial.

Results: Evidence-based PWC skills training programs are rarely used in current practice. The most commonly used training techniques are trial-and-error methods using verbal and visual cues, with safety maintained through proximity to the wheelchair. Clinicians experience tensions in providing client-centred practice in resource limited environments and maintaining safety during training while meeting the learner's needs.

There is a perception shared control technology may enable safe training opportunities and reduce training related anxiety and stress, however, clinicians require training and practice with new technologies to ensure competence.

The majority of the skills and abilities used when driving a PWC are mental functions, while knowledge of the self, environment, wheelchair, and activity or task are used during driving.

An errorless intervention for PWC skills training, facilitated by shared control, is safe and effective for training new wheelchair users with cognitive impairment. Participants felt safe and benefitted from the use of shared control.

Conclusion: Although many clinicians are hesitant to train individuals with cognitive impairments, learning is possible within this population. Shared control can facilitate errorless training strategies. Future research should incorporate alternative trial designs, integration into clinical practice, and wheelchair-related outcome measures validated for use with older adults with cognitive impairment.

Lay Summary

For individuals who struggle with mobility, a powered wheelchair can provide access to the community and improve health and wellbeing. Unfortunately, those who also have difficulty with memory or problem solving may have difficulty learning the skills they need to be safe and competent powered wheelchair drivers. Advances in technology, including the development of shared control of a powered wheelchair, allow for teaching opportunities which may be better for these individuals and promote safety for everyone during the learning process.

Preface

The research conducted for this dissertation was carried out in Vancouver, British Columbia, based out of the GF Strong Rehabilitation Research Program. I was responsible for developing the research program, including the design, execution, and data analysis of each of the four studies contained within, in consultation with Dr. William C. Miller (supervisor) and Drs. Ben Mortenson and Alex Mihailidis (supervisory committee). Approvals for the research were obtained from the University of British Columbia Behavioural Research Ethics Board (Chapters 2 and 3: #H14-00662 & #H15-02794, Chapter 4: H15-01868), the University of British Columbia Behavioural Research Ethics Board (Chapter 5: #H14-01702), Vancouver Coastal Health Research Institute (Chapter 2 and 3: #V14-00662 & #V15-02794, Chapter 4: #V15-01868, and Chapter 5: #V14-01702), and Providence Health Care (Chapter 5: #H14-01702). The CoPILOT RCT study was registered with ClinicalTrials.gov (Identifier NCT02982252).

A version of Chapter 4 has been accepted for publication in the American Journal of Occupational Therapy. A version of Chapter 5 has been accepted for publication in the Canadian Journal of Occupational Therapy. Versions of Chapters 2 and 3 will also be submitted for publication in peer-reviewed journals. Copyright permissions for accepted work are covered by the Copyright Transfer Agreement.

Each of the studies was conceptualized, including development of the research design by EMS and WCM. EMS completed the data collection and analysis, and prepared draft chapters/manuscripts for Chapters 2, 3, and 4. EMS supervised data collection, completed analysis, and prepared the draft chapter and manuscript for Chapter 5. WCM supervised all

projects, contributed to analysis and interpretation of the results, and provided feedback on and edited the chapters and manuscripts. WBM and AM were involved in study concept and formation for all studies and provided feedback on chapters and manuscripts. WBM supervised data collection for Chapters 2 and 3 and contributed to analysis and interpretation for components of Chapters 2, 3, 4, and 5.

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List of Abbreviations

ANOVA	Analysis of Variance
CHERRIES	Checklist for Reporting Results of Internet Surveys
CLT	Cognitive Load Theory
CoPILOT	Collaborative Powered mobility Innovative Learning OpporTunity
CoPILOT6	CoPILOT 6 session protocol
CoPILOT12	CoPILOT 12 session protocol
COREQ	Consolidated Criteria for Reporting Qualitative Research
EC	Expert Clinician
FCI	Functional Comorbidity Index
GDS	Geriatric Depression Scale
HAAT	Human Activity Assistive Technology model
HRQoL	Health-Related Quality of Life
HUI3	Health Utility Index 3
ICF	International Classification of Functioning, Disability, and Health
MCID	Minimal Clinically Important Difference
MoCA	Montreal Cognitive Assessment
MRC	Medical Research Council
OT	Occupational Therapist or Occupational Therapy
PIDA	Power Mobility Indoor Driving Assessment
PWC	Powered Wheelchair
RCT	Randomized Controlled Trial

RESNA	Rehabilitation Engineering and Assistive Technology Society of North America
TIDIER	Template for Intervention Description and Replication
UTAUT	Unified Theory of Acceptance and Use of Technology
VR	Virtual Reality
WCU	Wheelchair User
WheelCon-P	Wheelchair Use Confidence Scale for Powered Wheelchair Users
WheelTalk	Wheeling While Talking Test
WHO	World Health Organization
WhOM	Wheelchair Outcome Measure
WSP	Wheelchair Skills Program
WSP6	WSP 6 session protocol
WSP12	WSP 12 session protocol
WST-P	Wheelchair Skills Test for Powered Wheelchair Users
WST-Q-P	Wheelchair Skills Test Questionnaire for Powered Wheelchair Users

Glossary

Chaining: A training method which involves breaking a skill into steps, where the learner completes part of the task, and the trainer completes the remainder.[1]

Client-centred Practice: Individualized approach to clinical practice which is based on the client's autonomy and choice, through partnership between the therapist and client.[2]

Clinical Utility: Usefulness or potential uses of a technology or technique in a clinical setting.

Clinician: An individual who provides clinical services, including assessment and/or training across a variety of settings. May include occupational therapists, physical therapists, rehabilitation assistants, or assistive technology professionals.

Cognitive Impairment: Reduction in cognitive abilities, often associated with aging or disease, which may include memory loss.

Driving: Operation of a powered wheelchair, unless preceded by 'vehicle' in which case refers to operation of a motor vehicle (i.e., car or truck).

Errorless learning: Training processes which emphasize success in task completion, rather than correction of error. Errors are reduced or eliminated through trainer intervention to ensure learner arrives at correct response.[3]

Explicit memory: Memory of items which are known or can be declared (e.g., facts, words, descriptions of past experiences). Also known as declarative memory.

Extraneous Load: Cognitive load placed on a learner which is associated with the learning environment, inclusive of teaching methods used.[4]

Feasibility RCT: A randomized controlled trial designed to assess the feasibility of study procedures for a larger-scale trial.

Germane Load: Cognitive load associated with the cognitive process of learning.[4]

Grading: Training technique where the trainer provides progressively more difficult tasks, typically simpler variants of the desired outcome.

Implicit memory: Memory of items which are not typically in consciousness, including how to complete tasks (procedural memory).

International Classification of Functioning, Disability, and Health: A classification system of health and health-related domains, including Body Structures and Functions, Activities and Participation, and Environmental Factors.[5]

Intrinsic Load: Cognitive load placed on a learner which is inherent to the difficulty and requirements of the task being learned.[4]

Participation: Involvement in life situations, specifically activities of daily living and social engagement.[6]

Powered Wheelchair: A wheeled mobility device which uses electrically driven motors for forward propulsion.

Process Mapping: Visual representations of the progression of a task which outline the steps required, decision points and options for task completion

Residential Care: Living environment which includes 24-hour availability of nursing care, support for activities of daily living, and regular meals.

Shared Control: The use of teleoperation to simultaneously share control of a powered wheelchair or other device between the primary user and a second party.

Spaced Retrieval: Training technique where learned tasks are repeated with increasingly longer time between trials.[7]

Task Analysis: Systematic analysis of a task, breaking it down into component steps.[8]

Teleoperation: Remote operation of a device, in this case a powered wheelchair.

Think-Aloud: Research technique where the research participant verbalizes thoughts associated with a particular experience, with the intention of understanding conscious and subconscious processes associated with task completion.[9]

Trial-and-error: Training technique in which a learner attempts a task, identifies errors made, and corrects errors in subsequent task completion.

Acknowledgements

I have been very fortunate to have learned from many leaders in my field, who have each contributed immeasurably to my education as a scholar, researcher, and educator. I am immensely grateful to Dr. Bill Miller for his unwavering support and guidance as my PhD Supervisor. With Bill's support, I have been encouraged to take every opportunity provided to me to gain a wide array of skills and experience. His commitment to my learning as a graduate student and professional has provided an incredible foundation for success, and the graduate student environment and team he has fostered have been integral to my wellbeing and productivity throughout the past five and a half years. I would also like to thank Drs. Alex Mihailidis and Ben Mortenson for their commitment to my work as members of my supervisory committee. Their regular feedback and continued support enabled me to grow as a researcher and scholar and provided new and interesting insights into my work.

The members of the G.F. Strong Rehabilitation Research Program, both past and present, have played a critical role in the completion of my PhD. I am enormously grateful to Dr. Krista Best, Dr. Ed Giesbrecht, Dr. Tara Klassen, Lisa Simpson, Dr. Marie-Louise Bird, Dr. Delphine Labbe, Dr. Bita Imam, Dr. Dominik Zbogar, Dr. Oladele Atoyebe, Dr. Brodie Sakakibara, Dr. Adebimpe Obembe, Dr. Paula Rushton, Dr. Lisa Kenyon, and Shalaleh Rismani, for their contributions to my learning as peers, collaborators, and mentors. I feel so fortunate to have had the support of these peers which has enhanced my learning, and even more so for the friendships which have extended beyond our work. I will continue to cherish these into the future.

Dr. Ian Mitchell and his team were integral to the development and ongoing troubleshooting with our study technology. I am indebted to his team for having technical

knowledge and capabilities which I did not, and their prompt attention to any issues which arose. Without Dr. Mitchell and his team, half of this research would not have been possible.

I would not have been able to complete these projects without the commitment and support of Dr. Kate Keetch, Erica Digby, Naomi Bartz-McCormick, Laura Beer, Chris Yao, Colleen O'Melinn, Nathalie Manuel and the many undergraduate students and others who have contributed as work-learn students and research assistants. Similarly, I am indebted to the research participants, both clinicians and powered wheelchair users, and other collaborators who have shaped my experience and helped me to understand the meaning behind my work.

I would also like to acknowledge the incredible support of my family, Anne Campbell, Gary Smith, John Lindsay, Claire MacDonald, and Lauren Lindsay, and close friends, Dr. Rebecca Mason, Jennifer Amell, Joanna Fensome, Jonathan Logan and Kevin Hathaway. Each has provided support in the way I have needed it in the moment. I am very grateful for their continued presence and love. My extended family – aunts, uncles, and cousins have each played a role in celebrating my achievements and providing encouragement in the past five years. I am grateful for the wide-ranging support they have provided.

I am very grateful for support from the Canadian Institutes of Health Research, AGE-WELL Network of Centres of Excellence, Alzheimer Society of Canada, Canadian Occupational Therapy Foundation, International Collaboration on Repair Discoveries, and University of British Columbia, for providing both personal and research funding throughout my PhD. I am also grateful for the in-kind support provided by Permobil Canada and Sunrise Medical, in providing powered wheelchairs and a myriad of other technology for my work.

Finally, I would like to thank Doug Gayton, for launching and supporting me on this journey. Without his encouragement, my CCV would still be only 5 pages long.

For Ahillya Sankar, who always knew I would become a scientist.

Her passion for improving the lives of others, commitment to lifelong learning, dedication to the importance of science, and enduring curiosity and awe about the world have been inspirational to me.

Chapter 1: Introduction

1.1 Statement of the Problem and Rationale for the Research

Powered wheelchairs (PWCs) provide opportunities for individuals with limited mobility to participate in their communities, promoting independence, health, and general wellness. However, due to limitations in clinical practice, available training programs, and current technology, many older adults who might benefit from a PWC are denied access to one, or have their access removed following a safety-related incident. As a clinician, I have struggled with the decision to provide a PWC for individuals with substantial challenges with cognition and memory. However, I have also observed the potential for these individuals to learn and become competent PWC users through regular and sustained practice.

The rationale for this research stems from our clinical observation that individuals with cognitive impairment are able to learn, and from challenges expressed by clinicians and researchers in the field regarding available evidence and resources. Notably, we have observed that while there is agreement that powered wheelchair skills training is a critical component of the wheelchair provision process, and that training mitigates risk and promotes effective use, the training provided is often inadequate for the needs of the individual. Our understanding is that there may be a mismatch in training styles and learning needs, and clinicians struggle with limited evidence to support best practice in powered wheelchair skills training. Therefore, the focus of the research described throughout the following chapters is to systematically investigate how current practices in PWC training can be advanced, using an evidence-based approach, to ensure we are meeting the needs of this population and others who may experience similar limitations.

1.2 Powered Wheelchairs Promote Activity and Participation

Wheelchair use has the potential to improve activity and participation outcomes leading to improved quality of life in individuals with mobility impairment, through increased independence, social engagement, and mobility, and reduced reliance on caregivers.[10–14] Social isolation and reduced leisure activity, which may be mitigated through provision of PWCs, are also associated with poorer health outcomes, increased rates of depression, and decreased subjective well-being.[15–21]

For individuals who have difficulty with manual wheelchair use due to physical limitations (e.g., strength, range of motion, or stamina) a PWC may provide an opportunity for participation which would not be afforded otherwise.[12] As shown in individuals with severe disabilities, the introduction of a PWC can improve subjective health outcomes, including quality of life.[22] Given the range of benefits, failure to provide an opportunity for PWC use may result in reduced opportunities for socialization, participation in the community, and lower overall health outcomes.[12,22]

1.3 Powered Wheelchair Use is Increasing Among Aging Canadians

In Canada, there are an estimated 42 000 PWC users living in the community,[23] and an estimated 32 000 additional individuals who require a PWC but do not have access to one.[24] Recently published data suggest the use of wheelchairs (both manual and powered) increases with age, with those aged 75 or higher representing highest proportion of PWC users in the community.[25] Notably, and not included in population estimates cited above, as many as 55% of individuals living in residential care requires a wheelchair for daily use.[26,27] With an aging population, we can assume the prevalence of PWC use will increase.

1.3.1 Risks Associated with Powered Wheelchair Use

Despite the benefits of PWC use, it is not without risk. While Canadian statistics are not available, in the United States, there were an estimated 36 000 non-fatal accidents annually between the years of 1986 and 1990 related to manual and PWC use, with 7.6% of those involving others in the environment.[28] Studies investigating PWC safety specifically have also reported rates of accidents resulting in harm to the individual or the physical environment ranging from 13% to 21% over the course of four months to a year, suggesting there may be substantial risk to PWC users and others around them.[29–31] In residential care, this leads to specific concerns about safety for the community,[31] and clinicians may be more hesitant to provide powered wheelchairs to individuals who are perceived to present a risk to themselves or others. In addition to the risks of harm to users, others in the environment, or the physical environment, this risk to wheelchair users may also become more hesitant to participate in the activities they enjoy.[32]

1.4 Training Mitigates Risk and Encourages Safe and Effective Powered Wheelchair Use

PWC training has the potential to impact driving performance, increasing safety for the user and other individuals in their environment.[33–35] However, provision of PWCs is complex, because it is dependent on an individual's skills and abilities, including cognitive and perceptual abilities, diagnosis and prognosis, and the environment in which they live.[36,37]

PWC training is ideally completed by a qualified clinician, to ensure a match between individual need and ability.[38] The extent to which this service is being provided by rehabilitation clinicians (occupational and physical therapists) in publicly funded long-term or residential care facilities in Canada is not known. Clinicians train their clients in basic and skilled operation of

the PWC, as well as safety awareness and approaches, and consider both the capacities of the individual, and the characteristics of the environment where they are operating the PWC.[39] Ineffective wheelchair training which results in the individual being unsafe or unable to obtain a PWC may result in increased costs associated with reduced independence, including higher attendant care costs and greater caregiver burden.

For an individual in residential care to obtain or maintain access to a PWC, the user typically must demonstrate competence through a trial of the device.[31] Individuals must be capable of safely negotiating the environment and avoiding static and dynamic obstacles and be able to recognize when assistance is needed.[40] Following the trial, additional training needs may be identified to address limitations identified during the trial process. In a study conducted investigating guidelines for PWC use in residential care, a large majority of respondents felt more in-depth training was required when determining safety for PWC use, particularly when there are limitations to body functions including cognition, movement, or vision issues.[27]

1.4.1 Evidence Base for Powered Wheelchair Skills Training is Lacking

Training in PWC skills requires 1:1 time with a rehabilitation clinician with advanced education who is familiar with the requirements of PWC use,[37,38] and may include multiple assessments in addition to time for training.[41] For individuals who struggle with learning, including those with cognitive impairments, several trials and assessments may be required before a final determination is made regarding their suitability for PWC use. However, PWC skills training appears to vary widely by location and facility, often related to the demands of workload and capacity within the health system. Due to limited clinician time and high workload, individuals who may require more involved training above the facility standard may not receive the necessary training, limiting their ability to obtain or maintain use of a PWC.[37]

The quality of training provided is also limited by the paucity of evidence-based programs supporting such training. The Wheelchair Skills Program (WSP) has been documented for use with both manual and PWC users, however evidence of its effectiveness in PWC skills training is limited.[42] Furthermore, the WSP draws theoretically from Motor Learning Theories,[43] and does not address issues of cognition and memory in the training process. While the WSP [43] does outline considerations for PWC for each of 30 PWC driving skills, these are based on the clinical experience of the authors, rather than research investigating the requirements for skill completion.

1.5 Limitations of Current Powered Wheelchair Skills Training

Training in PWC is anecdotally based in trial-and-error methods, where the client is provided a task to attempt, and learns from errors made in the process. Clinicians identify errors made and provide suggestions to compensate for the difficulty the client encountered. Complex skills are initially attempted in simple environments (e.g., wide-open spaces, quiet hallways), where skills are practiced in isolation or simulated until the individual demonstrates competence. Once a clinician is confident the individual can perform the skill safely in a simple environment, they will attempt that skill in more complex or realistic environments. Safety is maintained through close proximity of the clinician, who physically intervenes to remove a hand from the joystick or to turn off the chair, should a safety concern arise.[43] This proximity can be difficult to maintain in tight environments, including elevators, bathrooms, and narrow doorways, or at higher speeds. In addition, there is limited independence for the individual early in the training process, until competence has been demonstrated and the therapist is confident in their abilities.

1.5.1 Need to Understand the Skills and Abilities Used when Operating a Powered Wheelchair

We currently have very limited understanding of the skills and abilities used when operating a PWC. There has been more attention paid to the skills required to complete manual wheelchair tasks than PWC tasks, exemplified by numerous publications describing the challenges and requirements to achieve and maintain a wheelie position,[44–46] a skill which is fundamental to multiple manual wheelchair tasks. There is very little research which systematically explores the skills required to complete PWC tasks, and the knowledge and abilities required for safety and proficiency. One cross-sectional study explored the relationship between PWC driving proficiency and visual function, visual perception, cognition, and personality, demonstrating strong correlations between these factors and PWC skill proficiency, as measured by a powered mobility road test.[47] Another cross-sectional study found a relationship between cognition and frequency of use, however did not address safety nor performance of PWC tasks.[48] Substantial attention has been paid to the requirements for driving a motor vehicle,[49–51] and many clinicians have relied upon this research to guide their understanding of PWC use, however these are different devices with different needs.[31,47] In particular, motor vehicle driving is governed by structure and rules which are not comparable to the experiences of operating a wheelchair on a sidewalk, which tends to be far less predictable. Furthermore, there are strict rules governing licensing for motor vehicle use, which have not been applied to daily mobility devices like PWCs.[31] Understanding the specific challenges and task demands of PWC use is imperative to the development and implementation of PWC skills training.

1.5.2 Limitations for Training Individuals with Cognitive Impairment

There is a paucity of research evidence to support training approaches for individuals with cognitive impairment. With limited clinical time available, clinicians may refuse to train individuals who will not learn quickly or easily. While it is expected that these individuals will require more assistance or time for training, or alternative teaching methods, these have not been reported nor systematically evaluated. Clinicians may also be concerned about risks associated with training, which they are unable to mitigate effectively, including risks to the individual training, others in the environment, or to the trainer themselves. As a result, individuals with cognitive impairments may not be receiving training suited to their needs, or any training at all,[37] and are therefore never given the opportunity to fully demonstrate their potential abilities with PWCs. Furthermore, for those experiencing cognitive decline or demonstrating challenging behaviours, wheelchairs which have been provided in the past may be removed, further constraining their independence.[27] There is a need for evidence-based protocols which allow clinicians to provide PWC training which is low risk to both the potential PWC user and the others who inhabit their environment, while providing the conditions necessary for optimal learning.

Meeting the specific learning needs of cognitively impaired adults is also necessary for success. When cognition is intact, learning new information or skills typically involves the use of short term and working memories.[52] With age-related cognitive decline, long term memory is often preserved, while working memories typically associated with learning, are affected.[53] Typical wheelchair skills training for PWC use involves verbal commands or visual cues with an associated response, and relies on short term, explicit memory, making it difficult for individuals with cognitive impairments. Trial-and-error learning is often used for PWC skill development,

which encourages the user to attempt a skill and benefit from errors made by attempting to avoid repetition of the actions which caused the error in the previous trial. For those with intact cognition, short term, working memory allows for memory of the error, and correction in subsequent trials. However, for those who experience difficulties with short term and working memories, it has been hypothesized difficulty with verbal recall may relate to challenges remembering operational instructions for the device,[48] in addition to remembering those actions which led to errors in a previous trial. This is supported by a cross-sectional study investigating the neuropsychological predictors of PWC use, which found verbal recall, visual construction abilities and general cognitive function, were predictive of frequency of PWC use.[48]

1.6 Implicit Learning as an Alternative to Trial-and-Error

Given the low potential for success with trial-and-error in populations with cognitive impairment, alternatives to trial-and-error learning should be explored. Individuals with cognitive impairment may be more likely to learn the correct responses through errorless learning, without having to rely on explicit memory processes for retaining memory of errors made in previous learning opportunities.[54,55] Errorless learning relies on implicit memory processes which remain relatively intact despite memory loss and other cognitive decline.[56,57] In the literature, these techniques have been largely applied to language disorders and learning declarative knowledge (e.g., word association) and have demonstrated success in both the learning and retention of new knowledge for individuals with impaired short term and working memories.[54,58] There is an opportunity to assess the effectiveness of these approaches for other tasks, including PWC skills, for individuals with similar challenges.

1.6.1 Errorless Approaches Applied to Procedural Skills

Implicit learning opportunities, referred to as errorless learning, have been shown to be particularly beneficial when learning how to complete new tasks (procedural knowledge).[59,60] Evidence from a pre-post case-controlled study suggests that individuals with Alzheimer type dementia benefit from implicit, errorless learning with both motor tasks and perceptual skills, despite having limited or absent memories of the initial training period, and maintain this learning after four weeks.[61] Learning is also enhanced through the use of natural environments (as opposed to clinics),[59,62] allowing the learner to generate cues based on personal experience and familiarity, which are then more likely to be maintained and recalled when completing the same or similar tasks in the future.[57]

1.6.2 Using Shared Control Technology to Facilitate Learning

A wheelchair training program which utilizes an errorless learning approach in natural environments may assist individuals with cognitive impairments to acquire the necessary skills for safe PWC use. However, it is difficult to provide opportunities for errorless learning without the trainer having adequate control of the wheelchair. Shared control teleoperation technology may help to provide the necessary conditions to teach PWC skills using an errorless approach. This technology was initially developed for use in research examining potential applications of an intelligent PWC in a residential care environment, using teleoperation to simulate the experience of an intelligent PWC.[63] In this process, we identified the use of teleoperation and shared control, where the individual could benefit from error correction where necessary, as a potential clinical tool. In fact, one participant expressed increased comfort in her independent driving skills in the process, contributing to a clinical question of whether learning facilitated using shared control might support the conditions necessary for delivering training using an

errorless approach.[64] The teleoperation technology would allow simultaneous control of a PWC between the users themselves (driver) and the clinician (trainer).

An intervention supported by this technology would potentially allow training in familiar environments with minimized risk and allow for greater modification and gradation of the difficulty of the tasks being taught. For example, a clinician may be able to practice the skill of navigating in a crowded environment earlier in the training process, enhancing the use of environmental cues, while maintaining safety for the user and individuals in their environment. Additionally, a clinician may be able to break down a skill into its component parts to teach specific steps of a skill, while completing the remainder of the skill on the client's behalf. This strategy, known as chaining, could provide opportunities for successful, errorless learning, while providing demonstration of the full skill.[1] There is an opportunity for shared control to promote enhanced safety during PWC training, and be used to assist in teaching skills through the use of demonstration, forward and backward chaining techniques, and grading of the difficulty of PWC skills.

1.7 Theoretical Approach to Teaching and Learning with Cognitive Impairment

1.7.1 Cognitive Load Theory

Cognitive Load Theory (CLT) posits there are three types of load which must be balanced to optimize learning. Intrinsic load is related to the effort inherent in the task being learned (e.g., navigating an elevator is inherently more complex than driving down a quiet hallway); extraneous load is related to the challenge posed by the way the material is taught, including the environment in which the person learns (e.g., dynamic environments are more challenging than static environments); and germane load is the effort required for the learning process itself.[65,66] Individuals who experience aging-related cognitive impairment, including

memory loss may have increased difficulty with information processing, due to impairments in short term and working memory, increasing germane load. Modified instructional strategies can help to balance this load by decreasing extraneous load in the learning environment, or by decreasing the intrinsic load by modifying the task.[62] Instruction based on CLT may compensate for memory deficits and allow more resources to be allocated to the process of learning (germane load).[66,67] Understanding learning from this theoretical basis supports the development of instructional strategies which emphasize the reduction of extraneous load by adjusting teaching methods and environmental demand, and reduction of intrinsic load by simplifying the task through an errorless approach.

1.7.2 Using the Komatsu Two-Factor Model to Apply CLT in Practice

In selecting methods for training, the Komatsu Two-Factor Model provides a framework to place training techniques along a bi-axial continuum, considering both the amount of error in the training approach, and the effort required for information retrieval.[68] The concept of error in learning has been explored; however, it has also been suggested that effortful, practiced retrieval of information enhances learning.[3] Learning approaches have been categorized according to this model to allow development of a training program, which maintains errorless approaches, while increasing effort over time. The learning approaches include demonstration and modelling, cued learning with and without fading (cues are removed over time or presented continuously), and spaced retrieval (skills which are proficient are repeated with increasingly longer retrieval periods).[58] This categorization allows selection of new approaches beginning with low error/low effort and moving to low error/high effort over time as the individual demonstrates increased skill, resulting in opportunities for progression, while increasing independence of skill completion over time. Although none of these approaches has been established as a single best

practice for teaching of procedural skills for individuals with cognitive impairment, each of these approaches has shown promise individually.[7,69]

1.8 Purpose of the Research

The overall purpose of the research described in the following chapters is ***to generate knowledge through end-user input to develop a wheelchair skills training program for older adults with cognitive impairment, using an errorless learning approach, and evaluate the feasibility of implementing this program in a randomized controlled trial for individuals living in residential care***. The specific objectives for this research are:

1. To understand and describe the current practices in PWC skill training to identify gaps, challenges, and limitations faced by clinicians in providing wheelchair skills training, and opportunities for improvement; and
2. To explore clinicians' perceptions about how a shared control teleoperation device for PWCs could be used in a clinical setting and to explore key features for the clinician interface (remote) for use during training; and
3. To systematically explore the task demands of PWC use, including frequently used skills, abilities, and knowledge; and
4. To develop and evaluate the feasibility of a randomized controlled trial investigating an errorless approach to PWC training used in residential care environments to train older adults with cognitive impairments.

1.8.1 Understanding Current Powered Wheelchair Skills Training

To effect change, it is necessary to examine current practices in PWC skills training to identify strengths, limitations, and challenges, which may provide opportunities for adjustment. In Chapter 2, we report on two studies, which explore current practices of clinicians who offer

PWC skills training. These studies include a North American survey, to understand the breadth of clinical practice for PWC skills training across a range of practice areas and populations, and a series of qualitative interviews to explore current PWC skills training practices in more detail and identify opportunities for the use of technology to enhance practice.

1.8.2 Exploring the Clinical Utility of Shared Control Technology for Powered Wheelchair Skills Training

Based on previous research conducted by our research team, we identified the potential for shared control technology to contribute to a novel training approach, which could focus on provision of safe and effective learning experiences. However, in order to use this technology in clinical practice, it was important to understand clinicians' perceptions on the potential clinical utility of the tool, and ensure it met their needs. Chapter 3 describes the results of qualitative interviews conducted as part of an iterative, user-centred design process exploring the potential uses, benefits, and drawbacks of shared control technology, applied to PWC skills training. The information gathered in this study informed further development of this technology, which was then incorporated into an errorless approach to PWC skills training.

1.8.3 Understanding the Task Demands of Powered Wheelchair Use

To develop a therapeutic intervention which focuses on procedural tasks through the use of errorless strategies such as cueing, modelling, and chaining it is also important to have a thorough understanding of the steps required to complete the task. The tasks can be modified or adjusted to accommodate for differences in individual learners and the learning process.[8] We require an understanding of the motor, cognitive, and perceptual skills required to complete each of those steps. Rehabilitation clinicians use an activity or task analysis approach to determine these steps and the skills, abilities, and knowledge required for the task being taught.[8,70] Chapter

4 describes a systematic approach to task-analysis for PWC driving, using think-aloud methods, which will contribute to the development of an errorless PWC skills training program for older adults with cognitive impairment.

1.8.4 Developing and Evaluating the Feasibility of a Novel Intervention for Powered Wheelchair Skills Training

Chapter 5 describes the development, implementation, and feasibility of an intervention for PWC skills training which incorporates an understanding of current clinical practices, the clinical utility of shared control technology, the task demands of PWC driving, theoretical principles of CLT, and errorless teaching strategies. Feasibility studies are particularly useful when evaluating technologies, which have not been used before in practice, to ensure effectiveness of the technology, and address feasibility concerns prior to moving to a larger study.

1.9 Study methodologies

1.9.1 Development and Evaluation of Complex Interventions

Complex interventions are described by the Medical Research Council (MRC) as "interventions that contain several interacting components."[71] These components may be related to the intervention itself, the population for whom the intervention is designed, or the need for flexibility or individualization in intervention delivery.[71] PWC skills training falls under this definition as it may be impacted by the type of training delivered, the individual delivering the training, a typically heterogeneous population, and the need for individualized intervention delivery. It is therefore prudent to consider the guidelines from the MRC on the development and evaluation of complex interventions throughout the course of this research. In particular, the MRC proposes a need for a strong theoretical underpinning (e.g., CLT) to the intervention, so

that causal links may be identified and strengthened, the use of multiple outcome measures to assess a range of potential outcomes, and flexibility within the intervention to allow for individual modification.[71] The MRC specifically identifies the need for assessing the feasibility of the intervention to test procedures, estimate the potential for recruitment and retention, and determine an adequate sample size for future research.[71] The MRC further recommends the use of a systematic, phased approach to intervention development which incorporates the best available evidence and theoretical approaches.[71] These factors are considered in the development of the intervention evaluated in a feasibility randomized controlled trial in Chapter 5.

1.9.2 Systems Model of Intervention Development

Rogers proposes applying a systems approach to the intervention development process, to ensure interventions specifically consider the tasks which need to be trained, the training design, and evaluation of that training.[72] The Systems Approach to Intervention Development applies a systematic method to the development of a clinical intervention to ensure all relevant theory and clinical practices are considered. Each component of this research corresponds with a component of the Systems Approach to Intervention Development seen in Figure 1.1.

This approach begins with a needs assessment, identifying the issue to be addressed – in this case the training of individuals with cognitive impairments in the use of PWCs. The needs assessment is an opportunity to explore the inherent challenges and scope of the issue.[72] Chapter 2 specifically addresses the needs assessment, through the use of qualitative interviews and a North American survey to understand current practices in PWC training, including challenges specific to older adults with cognitive impairments. Understanding user needs is also one of the key principles in user-centred design, the focus of Chapter 3.[73] To understand the potential role technology might play in facilitating training, Chapter 3 describes findings from qualitative

interviews exploring the clinical utility of the CoPILOT shared control system. To understand the relevant personal characteristics, which may impact the training process, and the task demands for indoor driving, Chapter 4 describes an understanding of the skills, abilities, and knowledge required to complete the task of indoor driving which has not, to date, been investigated and published in the literature. A training program designed based on the findings from the task analyses, incorporating training principles, previous training programs, and previous research is reported in Chapter 5. This will lead to a refinement of the intervention for future research, ultimately leading to training recommendations for application in clinical practice.

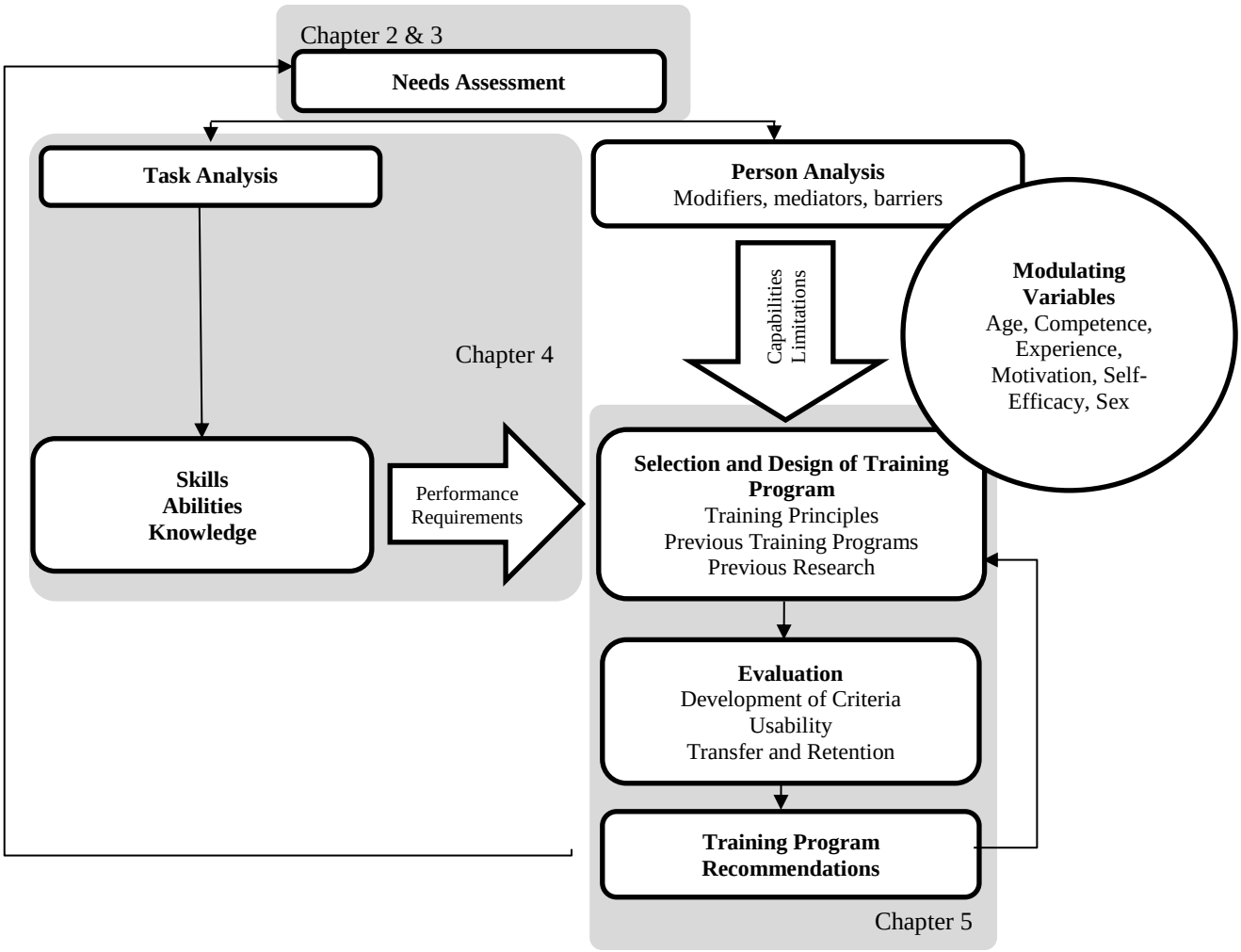


Figure 1.1 Systems Approach to Intervention Development (Adapted from Rogers, 2010)

1.9.3 Mixed Methodology in Rehabilitation Research

Mixed-methods approaches are well suited to rehabilitation research as they represent an opportunity to address the complexities inherent in rehabilitation interventions which may not be adequately addressed through either quantitative or qualitative methods alone.[74] Although there is an inherent tension between qualitative and quantitative methods due to their respective foundations in inductive and deductive traditions respectively, they each offer strengths to the unique needs of rehabilitation research.[75] Mixed-methods approaches can be distinguished by

their implementation sequence (sequential vs. concurrent), priority (exploratory, explanatory, or triangulation), and level of integration (research question, data collection, analysis, and interpretation).[75] Our research uses a sequential approach throughout the dissertation, maintaining distinction between paradigmatic approaches,[76] with giving priority to exploratory methods, and integration at the level of interpretation to address the overall purpose of developing and evaluating an intervention for teaching PWC skills to older adults with cognitive impairments. The use of mixed-methodology is a pragmatic approach which recognizes a false dichotomy between quantitative and qualitative approaches,[77] which allows us to capitalize on the benefits of multiple methodologies,[75] and ensure the method which is most suited to the specific objective is used.

Qualitative methods are well suited to exploratory studies, particularly in areas where there is little known.[75,78] In the rehabilitation literature, there has been minimal attention paid to the training of users of PWCs, making the topic well suited for exploratory study. As such, Chapters 2-4 focus on qualitative methodologies, which will provide greater insight into the current practices, needs, and requirements of PWC training. Overall, these qualitative methods are approached using a post-positivist paradigm. This exploratory work will help develop an intervention, which can be evaluated through both quantitative and qualitative approaches.

Mixed-methods approaches have been highlighted for their suitability for evaluative work, particularly where interventions are complex, and may not be well served by one approach alone.[75] As this is a relatively new area of research, Chapter 5 describes a feasibility approach, which addresses both process and clinical outcomes. To address these, it is beneficial to capitalize on quantitative and qualitative approaches to fully understand the feasibility successes and challenges, which will inform future research protocols, provide evidence of the effect of the

intervention, and explore how the intervention was experienced.[79] Feasibility approaches are inherently evaluative, and in this case, we will use quantitative and qualitative findings interpreted together to evaluate the potential for the intervention's use in future research, as well as its use in clinical practice.

1.10 Summary

Complex intervention development necessitates the use of theoretically informed concepts and evidence-based approaches. However, in the case of PWC skills training, there was limited evidence from which to base a novel intervention to address the needs of older adults with cognitive impairments. While CLT represents a platform from which to build an intervention, the critical building blocks of understanding PWC skills themselves, in addition to clinical practice in PWC skills training, were missing from the evidence-base. Therefore, in the absence of substantial evidence in the literature it was necessary to create evidence from which to build this intervention. The subsequent chapters describe three studies, which address this gap and contribute to intervention development, followed by the evaluation of the feasibility of an errorless approach, based on the principles of CLT, for PWC skills training for older adults with cognitive impairment.

Chapter 2: Current Practices in Powered Wheelchair Skills Training

Participation is defined by the International Classification of Functioning, Disability, and Health (ICF) as involvement in life situations, and is considered a fundamental right by the World Health Organization (WHO).[5,80] Participation is a critical concept in disability and rehabilitation as it is associated with quality of life, health, and rehabilitation outcomes.[81] Wheelchair skills play an important role in mediating the known benefits of wheelchairs for improving participation among individuals with limited capacity for ambulation.[12,29,31,82] A systematic review of factors impacting participation in wheelchair users found wheelchair skills were one of the modifiable factors found to be related to community participation.[83] In an analysis of wheelchair users in residential care, wheelchair skills including maneuverability, independence in activities of daily living, and use of a powered wheelchair (PWC) were the most important predictors of mobility.[21] In the same population, wheelchair skills were also found to be correlated with participation frequency and were the best predictor of participation.[82]

Furthermore, wheelchair skills training has the potential to promote safety for the wheelchair user and others in their environment. For users of PWCs, safety may be impacted by impaired cognition, sensory status (especially vision), and driving skill.[47] As a result, many individuals with these impairments who might otherwise benefit from PWC use are not provided the opportunity, based on concerns for their or others' safety.[27,31,36] Training in wheelchair skills provides an opportunity to mitigate these risks. Two studies including wheelchair users and other stakeholders in residential care found that stakeholders perceived a need for additional training to determine safety for people with cognitive, movement, or vision related issues.[27,31]

Skills training can address a range of challenges with PWC use. Notably, research suggests difficulty maneuvering in tight spaces, basic (e.g., 90 degree turns) and community

mobility (e.g., crossing streets) skills, and obstacle avoidance remain difficult even for some experienced users.[84] A qualitative study of young people's experiences receiving PWCs found they were given basic safety instruction in the use of their wheelchairs, however they continued to have difficulty for more challenging driving tasks.[85] The authors identified a need for increased training in managing risky situations and wheelchair related problem solving.[85] In a qualitative study exploring men's and women's experiences with PWCs, participants indicated the PWC increased their ability to engage independently in everyday tasks, however they struggled with the use and function of the PWC.[86] Participants found the PWCs were too complicated, and presented undue risk.[86] As a result, they reported avoiding crowded places in order to maintain safety. One of the reasons cited for these challenges was insufficient training.[86] Wheelchair skills training rates reported in the literature are as low as 1 in 2 individuals in rehabilitation.[87]

To develop the skills necessary for safe and effective driving, a trial of a PWC with comprehensive training is ideal.[27] New users need to learn maneuverability skills, driving strategies, and skills required to share space (e.g., dynamic obstacle avoidance, driving etiquette) with others in their environment, tasks identified as difficult in studies investigating the experiences of PWC users.[29,31] Given the importance of training to a user's safety, capacity, and performance, training is recognized by the WHO and the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) as an integral part of the wheelchair service provision process.[88,89] Training is used to help prevent adverse events, improve use of the device, and reduce device abandonment. Training may also be used to adjust PWC programming parameters to ensure effective and safe use of the chair in particular environments.[31] Available standardized programs for training in PWC skills include the Wheelchair Skills Program

(www.wheelchairskillsprogram.ca; WSP) and the Driving to Learn Program, however each of these has seen little integration into common use by clinicians despite ongoing knowledge translation efforts.[87,90] Furthermore, there has been neither sufficient nor consistent evidence regarding the effectiveness of these programs to incorporate these into clinical practice guidelines and best practice documents. Although both pre-post and randomized controlled trials using the WSP have demonstrated a statistically significant improvement in the PWC skills of adults undergoing rehabilitation post-stroke with as little as 5x30-minute training sessions,[33,91] no difference in PWC skill capacity was found in a larger non-diagnostic specific randomized controlled trial using the WSP at the same intensity.[42] However, PWC skills training in the larger trial did result in higher levels of goal attainment, goal satisfaction, and wheelchair skill performance as compared to a standard of care control.[42,92] Given how little evidence there is to support the few existing programs, and a gap in the literature on the content, process, and effectiveness of training methods, it is clear there is a need to continue developing this area of research. To address the need for the development, validation, and implementation of evidence-based PWC skills training programs, it is important to begin with an understanding of current practice to identify gaps, challenges and barriers faced by clinicians in providing wheelchair skills training, and opportunities for improvement. A greater understanding of current practice will also provide an understanding of customary care which may be compared to new programs to establish their efficacy and effectiveness.

2.1 Objective

The objective of this chapter is to describe current practices in PWC skill training and identify and understand gaps, challenges, and limitations faced by clinicians in providing wheelchair skills training.

2.2 Methods

To address the chapter objective, we conducted two studies: a qualitative study using semi-structured interviews and a survey consisting of both closed and open-ended questions. Two methodologies were included to ensure the objective could be met with sufficient breadth and depth. The methodology and results are presented in the order the studies were completed. The qualitative interviews were conducted first; however, over the course of this research we determined there was a need to have more breadth in our understanding of PWC skills training across a wider geographical area. This resulted in the development of the survey, with questions informed from the discussions with participants in the qualitative interviews.

2.2.1 Qualitative Interviews

We employed qualitative description design, with semi-structured interviews followed by thematic analyses, with a post-positivist paradigm.[93,94] The following methodology and results are presented according to COREQ reporting standards.[95]

2.2.1.1 Study Objective

The objective of this qualitative study was to explore the current practices of rehabilitation clinicians in providing PWC skills training, including challenges and techniques for meeting the learning needs of individuals with cognitive impairments.

2.2.1.2 Participants

Participants (n=15) consisted of rehabilitation clinicians (occupational and physical therapists) with experience providing PWC skills assessment and training to older adults and individuals with cognitive impairment. We recruited participants purposively for maximum variation in clinical expertise (i.e., length of time practicing, experience in varied practice settings, experience prescribing PWCs) and population served (i.e., level of care, age, diagnosis

of clients). Participants were required to speak English well enough to respond to open-ended questions about their practice. Fifteen participants were included to ensure sufficiency of the data.[96] Sufficiency in qualitative research is defined as the point at which new data fits easily within existing themes and codes.[96]

2.2.1.3 Recruitment

Participants were recruited through personal networks of the investigators within the clinical community, and through a network of practicing clinicians in wheelchair seating and mobility in British Columbia. We contacted prospective participants by email and provided them with a summary of the study objectives and methods prior to signing informed consent. No prospective participants declined to participate.

2.2.1.4 Semi-Structured Interviews

Participants completed a semi-structured interview, which focused on their current and past practices in PWC training. Additional data collected during the qualitative interviews was related to the clinical utility of a novel shared control training tool; these data are reported in Chapter 3. Interviews were held in person at a location of the participant's choice (typically the researcher's or participant's office) or over the phone where distance precluded an in-person meeting. All interviews were audio recorded and transcribed verbatim. Selected participants also completed a second and/or third interview specifically focused solely on the prototype device; these additional interviews will be described in Chapter 3. Interviews lasted approximately one hour and consisted of open-ended questions. Full text of the semi-structured interview guide can be found in Appendix A. Up to three graduate student interviewers were present for each interview. The primary interviewer (EMS) was a clinician (occupational therapist) with qualitative research training, and experience in PWC assessment and training, including

experience in the clinical settings where some of the participants were employed. The other two interviewers included an engineer (SR; biomechanical) with experience in assistive technology development, and a computer science graduate student (TJ) working on the development of new PWC technology. Neither the engineer nor the computer scientist had a pre-existing relationship with any of the participants. All interviewers were female. The purpose of the study, including intended use of the data for integration into the primary interviewer's dissertation work, as well as credentials and professional backgrounds of the interviewers were reported to the participants prior to commencing the interview.

2.2.1.5 Analyses

To complete analyses of the qualitative interview data, we used Braun and Clarke's six-phase framework for thematic qualitative analyses.[94] To begin, each interviewer familiarized themselves with the data by reading the interview transcripts. Line by line coding of interview transcripts was completed by two investigators (ES & SR) who had conducted the interviews to generate initial codes. I (EMS) then completed three additional rounds of coding using Microsoft Excel™ software to consolidate codes and identify themes. Following each round, I reviewed quotes with feedback from the research team and one member of my thesis committee (WBM) to ensure consistency with the code assigned and identify any which required revision. Themes were constructed from the final codes to represent areas of tension in the data, and refined following discussion with a member of my thesis committee (WBM).

2.2.1.6 Trustworthiness

Strategies to maintain trustworthiness were used to enhance credibility, dependability, transferability, and confirmability of the data.[97,98] To enhance credibility and transferability, participants were recruited purposively to ensure a range of practice experiences, populations,

and settings.[98] Study procedures, and a description of participants are reported in detail to promote dependability and transferability. Finally, confirmability is enhanced using multiple participants and interviewers, a detailed methodological description, and the presentation of both convergent and divergent data, where there may be data suggesting a lack of agreement within each theme. Given my role of primary interviewer as both a clinician, and former colleague of some of the participants, we used journaling and reflexive discussion among interviewers to promote reflexivity on my role as the interviewer, and reflections on findings which diverged from my own clinical experience. I specifically considered my assumptions based on my own experience in clinical practice. This included an assumption of a low level of PWC skills training, and an assumption that the training provided was not meeting the needs of individuals with cognitive impairment.

2.2.2 Survey

We conducted a cross-sectional, open, online survey, consisting of both closed and open-ended questions. Study methods and results are described according to the CHERRIES framework for reporting results of online surveys.[99]

2.2.2.1 Study Objective

The objective of this study was to identify the processes, techniques, facilitators and barriers in current powered mobility training in North America across a variety of populations and practice settings.

2.2.2.2 Participants

Our convenience sample of volunteer participants (n=263) was included if they were occupational therapists, physical therapists, assistive technology professionals, seating and mobility specialists, rehabilitation assistants, or otherwise involved in the assessment and

training of clients for PWC use. To be eligible, participants must have been working in Canada or the United States of America and able to respond to the survey in either English or French.

2.2.2.3 Recruitment and Consent

Links to the online survey were emailed to mailing lists of participants who had agreed to participate in future research and posted on online forums which focus on wheeled mobility. Survey recruitment notices were also sent to occupational therapists in Canada through provincial occupational therapy societies, and to occupational and physical therapists throughout the USA through national associations focused on wheeled mobility and assistive technology. Depending on the constraints of the listservs and forums used, up to three follow up emails and postings were sent at two-week intervals following the initial posting. The survey was open for responses over a six-month period from January to June 2016.

A page detailing information about the survey and investigators was located at the start of the survey to inform consent. A single dichotomous question on this page sought consent to proceed with the survey. Individuals who consented were directed to the survey on the subsequent page. No personal data were stored for individuals who did not consent to participate.

2.2.2.4 Survey Content and Delivery

The survey included demographic information (i.e., location, length of time practicing, level of education, practice setting and population), and multiple choice, checkbox, and open-ended questions. Training related content was informed by questions arising from the qualitative interviews and focused on evidence-based programs used in practice, skills trained during PWC skill training, number and length of sessions, training techniques, maintaining safety in the training process, training and cognitive impairment, and barriers and facilitators to training. The survey was written in English and translated into French using a two-step translation/back-

translation process. We used FluidSurveys™ to deliver the survey, which allowed language selection, and provided anonymized data for analyses. Full text of the English-language survey can be found in Appendix B. The survey was piloted by members of the research team and graduate students to identify concerns with the mechanism of delivery. Prior to analyses, we identified and remoted duplicates based on location and demographic factors. We excluded responses from analyses if individuals had not completed a minimum or one demographic question, or a minimum of one content related question.

2.2.2.5 Analyses

2.2.2.5.1 Demographics

Demographic data are presented using descriptive statistics for count, proportion, mean and standard deviation where applicable. For professional affiliation, where two were indicated in the 'other' category (e.g., PT and ATP), the professional clinical training with the highest level of education was selected (e.g., PT). In open-ended questions, or questions where 'other' was selected prompting an open-ended response, responses were grouped to minimize the number of responses. For example, the term 'general adult' was used to apply to area of practice when the terms all, mixed, general rehabilitation, or adult physical medicine were used, while the term 'geriatric' included notation of residential care or dementia. Individuals who indicated they worked in stroke were categorized as working in acquired brain injury/traumatic brain injury.

2.2.2.5.2 Analyses

Results are reported using descriptive statistics. Demographic data are presented using proportion, means, and standard deviations where appropriate. Multiple choice questions which required respondents to choose one option were represented by percentage. As respondents were not required to answer all questions, percentage represent the number of responses for each item

divided by the total number of responses for that item and multiplied by 100. Checkbox questions, where respondents were able to choose multiple answers, are also represented by percentage. For these questions, percentages represent the number of responses for each item, divided by the total number of respondents for the question in total. We used a content analysis approach to list and categorize open ended questions.[100] Similar items were grouped into categories (e.g., don't have enough time and need more time were categorized as 'limited time for training').

2.3 Results

2.3.1 Qualitative Interviews

2.3.1.1 Participant Demographics

Fifteen rehabilitation clinicians participated in this study; fourteen occupational therapists and one physical therapist. Clinicians' years of experience working with PWCs ranged from less than five to greater than twenty years. Twelve participants were female. Table 2.1 provides information on each participant, with pseudonyms used in the description of the results.

Table 2.1 Participant Demographics

Pseudonym	Practice Setting	Client Population	Years Practicing[1]	Years w/ PWCs[1]	Sex
Eleanor	Residential Care	Neurological	20+	10	F
Rebecca	Rehabilitation/Community	Older Adults	5	5	F
Jennifer	Community	ABI	20+	15	F
Marie	Residential Care	Older Adults	20+	20+	F
Elizabeth	Residential Care	Older Adults	20	5	F
Chris	Rehabilitation	SCI	5	5	M
Jillian	Residential Care	Older Adults	5	<5	F
Daniel[2]	Rehabilitation	Adults (all)	20+	20+	M
Natalie	Residential Care	Older Adults	20+	15	F
Caitlin	Residential Care	Older Adults	20+	5	F
Sarah	Residential Care	Older Adults	20+	20+	F
Fiona	Community	ABI	20+	20+	F
Agnes	Residential Care	Older Adults	10	5	F
Roger	Community	Adults (all)	15	10	M
Carmen	Community	Developmental Disabilities	20+	20+	F

Abbreviations: ABI: Acquired Brain Injury; SCI: Spinal Cord Injury
[1]Length of time practicing and years working with individuals in PWCs were rounded to the nearest 5-year interval to protect participant anonymity.
[2]Physical therapist; all other participants are occupational therapists

2.3.1.2 Thematic Analysis

We identified two major themes representing specific tensions in the provision of PWC skills training. The first, *Client-Centred Practice Minus Resources = Gatekeeping*, refers to challenges clinicians face in maintaining a client-centred practice in the face of limited resources. Despite a desire to remain client-centred, clinicians find themselves acting as gatekeepers for PWCs, allocating scarce resources only to those clients who have the most potential for success in the training process. The second theme, *Trading Training Practices for Safety*, explores the tensions inherent in the use of training tools and techniques which meet the learning needs of their clients, while maintaining safety for the client and those around them. This theme explores how often the tools and techniques used for training and the maintenance of safety are sometimes at odds with one another. This tension is particularly noticeable when working with clients with cognitive impairments. A table of themes for all chapters can be found in Appendix C.

2.3.1.2.1 Client-centred Practice Minus Resources = Gatekeeping

All participants discussed a commitment to client-centred practice, where the training program is tailored to the individual goals and needs of the individual. Daniel, a participant working in a rehabilitation centre discussed the importance of "matching the environment to the client's needs, matching the chair to the client's needs and then giving them appropriate tasks that challenge them – that are retainable, but challenging." The time used for training was also noted by several participants as being flexible, depending on the individual. For example, Fiona, an occupational therapist working in the community with adults with acquired brain injury noted they "could spend an hour a day, 5 days a week…" while Daniel indicated that "as long as there's progress, or you sense that there's potential for an 'aha' moment, then you keep going as long as the client's able to do it, and you got the time to do it." The ability to engage in client-

centred practice was seen by several participants as dependent on the environment in which one was working. Natalie, an occupational therapist with previous experience across multiple settings, indicated “one of the wonderful things about that environment [residential care] is that most people weren't leaving very quickly and so that process [training] could go for months.” The focus on client-centred practice was also apparent in recent shifts in practice in terms of who would be considered for PWC skills training. Fiona noted that her colleagues “were just starting to consider power mobility for clients who had strokes. Because the concern was around cognitive issues and perceptual issues and so I have seen a swing from ‘no, they can’t’, to ‘yes, they can’.”

However, there appears to be a tension between the limited resources experienced by clinicians, and the desire to provide training in a client-centred way. Carmen, a community occupational therapist working with adults with developmental disabilities, shared her concerns about limited resources to address safety. “It depends on the person. I'm thinking of this client who I had lots of safety concerns. Each session would be about an hour, hour and a half from start to finish, and I was able to do four of those, but I had to hand it over to his caregivers, cause I couldn't do it anymore.” Caitlin, an occupational therapist working in residential care, described this tension in terms of time to ensure a client had the opportunity “to continue to practice, because there comes a point where you realize, ok, no amount of practice is going to really make them pass, or get them to be safe. But at the same time, you feel like you owe them the due diligence of enough time to get used to this.”

Some participants resolved their concerns with having enough time by asking caregivers or equipment vendors to provide additional practice time for the client. Elizabeth, an occupational therapist working with older adults in residential care, shared her experience with

finding time and resources to work with her clients: “If we are lucky enough that they have got a companion… then we can ask them, and they are usually happy to do that. Rehab assists have limited time for the one on one activities unfortunately - but sometimes they can do short sessions with people.” While allowing for additional training time, and overcoming limited resources, participants were concerned about the quality of the training provided by non-clinicians. Jennifer, a community occupational therapist working with clients with acquired brain injury described this challenge: “Sometimes I use vendors… to take the client out a few more times. I’m reluctant to do that. It depends on the vendor.”

Available time was not the only barrier expressed by clinicians. Rebecca, an occupational therapist working with older adults in the community, described her challenges with obtaining the appropriate equipment to provide a client-centred approach. “If I'm lucky enough to have a chair that has multiple settings, I get them to program, you know, the indoor and the outdoor slightly faster so that I can use that to change my speed but often my clients don't afford those types of chairs and therefore don't get trials on those types of chairs.” Clinicians also felt they needed guidance on training programs and approaches. Jennifer, a community occupational therapist wondered “if there was something out there that gave some kind of guidelines around training process … I don't know that I use specific techniques. … what we do, is just what seems to be working at that moment with that client,” indicating a desire to be client-centred, while also recognizing a lack of access to evidence-based programs for training.

As a result of these limited resources of time, equipment, and available programs, participants noted they often act as gatekeepers, choosing which clients will have the opportunity to engage in training based on their likelihood of success. Jillian, an occupational therapist working with adults in residential care talked about who might be chosen to engage in PWC skill

training. “We have such limited power chairs and resource of therapists to train them, that if someone was … pretty cognitively impaired, we probably wouldn't even go down that road.” Some clinicians also spoke about who might be a more attractive candidate for training. For example, Agnes, an occupational therapist working in residential care, discussed how a person’s goals, funding, and age might make them more attractive as a training candidate. “There's the other people where we just kinda go, ok, you've done this before, you're 55, you're ministry funded, you really really really wanna do this, and you have very specific clear goals as to what you want to do with this power chair, then those are the ones where we sort of put our energies and efforts into.” Identifying those clients with the highest likelihood of success for training may allow clinicians to practice in a client-centred way for those clients, despite lower resource levels.

While clinicians commonly expressed this gatekeeping experience, they also spoke about how this caused them distress, as it was not truly client-centred. Roger, a community occupational therapist working with adults stated: “If I'm denying someone… the chance to have freedom of mobility through my recommendations, then I'm not giving him a fair shake, I'm not giving him a chance, that's not client-centred, it's not therapeutic. It's garbage.” Similar statements from other participants also expressed concern at not being able to provide the kind of client-centred care they were committed to, due to their limited resources.

2.3.1.2.2 Trading Training Practices for Safety

This theme explored the tensions between providing training which meets the client’s learning needs, including the use of specific training techniques, and maintaining safety for the client and others around them. These tensions were evident when looking at techniques used for training versus safety, which are often at odds with one another.

Participants described a variety of training techniques or tools they used in their practice to meet the specific learning needs of their clients. The use of verbal and visual cues was commonly described in addition to the use of hand over hand guidance. However, the use of evidence-based approaches was not frequently discussed. As Daniel noted, he does not "use any of the established training protocols. I find them a bit too rigid." In lieu of evidence-based protocols, participants generally start training in simple environments, and progress to complex environments as the client's skill improves. Marie, an occupational therapist in residential care described the "first goal is to drive independently indoors. So, there is no outdoor driving for anybody until you're proficient. Because it is easier to control the environment in the facility, but not so much when you're in the mall and there are people darting all over the place." This was echoed by Natalie, who said she "wouldn't move forward into a more congested or a more demanding environment until I was more comfortable that they were meeting the demands." Sarah spoke about adjusting her training in other ways, including how she would "grade the speed, I'd grade the complexity off the route, I'd grade the amount of stimuli they're having to deal with, whether we put them in a quiet corridor or a busy dining room." Adjustments to the environment of use was a common way of addressing safety concerns, while providing opportunities for learning.

While simplified or simulated environments were used by the participants to promote safety in learning, others noted the drawbacks associated with learning in these environments. Rebecca described how she would "tend to use things like chairs because they do not hurt when they bump, but that's not the most natural place anybody would be parking their wheelchair in a big open room next to a chair." Sarah noted similar concerns, as she believed "[clients] need to be out in the real environment, because you want to see how they're managing with traffic and all

of that kind of stuff. The real-world stuff, because that's the stuff that's gonna impact them. You know, you can't really simulate that." Caitlin suggested the real environment may be more effective for learning, as "it's better for them to be in their environment right away, having more experience to get from their room to the dining room. The more time using it in their actual environment, the better." While clinicians seem to prefer the safety of a simulated environment, they recognize simulation may not be ideal for the learning experience. This is representative of the type of tensions clinicians experience between safety and learning experiences on a regular basis – environments must be managed to maintain safety; however, clients also need to learn to drive in natural environments which are necessarily more complex.

Maintaining safety was a primary concern when training clients to use a PWC. Many clinicians, like Fiona, indicated they would maintain safety by "choosing the time when they are doing training, so less people, more people…. It would also be how close I am to them" or by positioning herself "beside them where the controls are so that I can intervene." Others, like Roger, suggested they would "never [be] outside of a few feet of my clients when they are operating." Still others, including Sarah, indicated they maintained safety by "taking the chair away as soon as we're done the training, so we don't give them the opportunity to be in the chair." The constant presence of a trainer to prevent the client from injuring themselves or others, or even the complete removal of a chair when the trainer is not present is seemingly at odds with the desire to provide real-world client-centred training.

Many clinicians discussed heightened safety concerns when training individuals with cognitive impairments. Caitlin described impairment with short term memory as a challenge "cause there's been times where I've taught something to someone and they just don't recall it from session to session, so that becomes a safety issue." For some participants, these issues could

be addressed through modified training techniques, for example, Fiona indicated “I use a lot of repetition… I would try to incorporate some errorless learning if possible, gradually reducing [input] as they pick up skills.” Others, including Roger, indicated they “give people more time to try and habituate… more opportunity to try and learn the skills just through practice and repetition.” Participants also discussed changes in how they would provide verbal cueing. Daniel noted that his “instructions would be a lot clearer… I might demonstrate, I might get in a chair myself and show them. I might walk them through… pushing the chair. Whatever it takes for them to understand.”

There were a variety of PWC programming parameters participants described they might change to provide an optimal learning environment, or to promote safety. As was described by Daniel, it’s “[…]sometimes counterintuitive – for instance, people with cognitive impairment, if a chair is programmed really really slow or really unresponsive so… there’s less likelihood of causing damage when they hit something, there’s not enough stimulation, the chair’s not moving quickly enough for the person to be engaged and maintain that concentration.” Rebecca described using programming parameters to problem solve why a learner might be “having a really hard time turning… is it because the chair is turning faster than they are able to react, or [are they] having some other conceptual difficulty.” While Eleanor described many parameters she would change, including forward and reverse speed and acceleration, she also described a tension with changing parameters for safety which had a resultant impact on learning. As an example, “sometimes we’ll turn down the torque on some chairs [if they are] running into things, but you need enough torque … to be able to get up the hill.” This tension between programming parameters which promote safety, and those which promote function, was evident throughout the interviews.

2.3.2 Survey

A total of 263 individuals completed all or part of the survey. In addition, 13 individuals did not consent to participate, and 82 individuals completed demographic questions, but did not complete a minimum of one content related question. We removed 1 duplicate survey (identical demographic and location information), and 4 surveys from participants who did not reside in Canada or the United States of America. Respondents worked in 9 Canadian provinces and 37 American states. Most respondents were occupational therapists, and over half of respondents were from Canada. Geographic location and professional affiliation of survey respondents are found in Table 2.3. Additional demographic characteristics (level of education, clinical experience, practice setting, and area of practice) of respondents are found in Table 2.2.

Table 2.2 Proportion (%) of Respondents by Country and Professional Affiliation (n=263)

	All	OT	PT	ATP	RA	SMS	Other
		64.6	**22.4**	**8.7**	**0.4**	**1.9**	**1.5**
Canada	53.6	51.7	0.8	0.4	0.4	-	0.4[1]
USA	46.4	12.9	21.7	8.4	-	51.9	1.1[2]

Abbreviations: OT: Occupational Therapist, PT: Physical Therapist, ATP: Assistive Technology Professional, RA: Rehabilitation Assistant, SMS: Seating and Mobility Specialist
[1]Not specified; [2]Rehabilitation Technology Suppliers.

Table 2.3 Demographic Characteristics of Survey Respondents

Level of Education (% respondents)	
Secondary School	0.8
Trade College/Diploma/Certificate	1.1
Associate Degree	1.1
Undergraduate (e.g., BA, BSc)	40.7
Master (Clinical, e.g., MOT, MPT)	26.2
Master (Research, e.g., MSc, MA)	11.0
Doctoral (Clinical, e.g., DPT/OTD)	12.9
Doctoral (Research, e.g., PhD, EDD)	3.4
Unknown	0.4
Clinical Experience (Mean, SD)	
Years practicing	18.05 (10.93)
Years working with PWCs	12.88 (9.40)
Practice Setting (% respondents[4])	
Community/Home Based Care	36.1
Extended/Residential/Long Term Care	25.9
Acute	11.0
Inpatient Rehab	18.6
Outpatient	37.3
Schools	1.5
Specialized Clinic	19.77
Wheelchair and Seating	*9.5*
Condition Specific[1]	*7.6*
Assistive Technology Centre	*2.7*
Other	8.4
Academic	*1.9*
DME Sales	*2.4*
Consulting and Private Practice	*2.7*
Corrections	*0.4*
Other[2]	*1.1*
Area of Practice (% respondents[4])	
Neurology	37.3
Geriatric	14.4
Pediatric	11.4
General Adult	34.6
AT Assessment	1.9
Seating and Mobility	9.1
Developmental Disability	3.4
Musculoskeletal	12.2

Area of Practice (% respondents)	
Acquired and Traumatic Brain Injury, Stroke	11.0
Orthopedics	6.5
Other[3]	6.8
Age of Clientele (% respondents[4])	
12 and under	28.9
13-19	41.4
20-64	83.3
65-84	81.4
85+	71.5

[1]Specific conditions include: Geriatric, Motor Vehicle Accidents, Amyotrophic Lateral Sclerosis, Muscular Dystrophy, Multiple Sclerosis, pediatrics, pulmonary rehab, Spinal Cord Injury, developmental disabilities, ventilator care, wound, neurodegenerative
[2]Other practice settings: Veterans hospital, Mobile Service, Manufacturing
[3]Other areas of practice: Multiple Sclerosis, Cerebral Palsy, chronic disease, intellectual disability, mental health, home health, oncology, amputations, palliative, rural, hands, sales, academic, respiratory, case management, cardiopulmonary, custom rehab technology
[4]Respondents were able to choose more than one response; total may equal greater than 100%

2.3.2.1 Evidence Based Skills Programs Used in Practice

Respondents were asked which, if any, evidence-based skills training programs they used in practice (in part or in full). The majority (59.5%) indicated they did not use any evidence-based skills training programs. The Wheelchair Skills Program (WSP) [101] was used by 31.7% of respondents, while Driving to Learn[102] was used by 3.4% of respondents. Just over 5% indicated they used other training programs, including informal training programs, training loosely based on existing programs (i.e., WSP and Driving to Learn), or programs described in the literature, including the Power Mobility Indoor Driving Assessment (PIDA)[103], and the Ranchos Los Amigos driving training program.

2.3.2.2 Skills Trained for Powered Wheelchair Driving

Over 90% of respondents indicated they always or almost always trained clients in the use of PWC controls (e.g., turning on, joystick operation), charging and basic maintenance, transfers to and from the wheelchair, basic mobility (e.g., driving forward, right and left turns),

speed control, and drive mode awareness and selection. Fewer than half of respondents indicated they almost or almost always trained clients in incorporating PWCs into instrumental activities of daily living, and procedures for using public and personal transportation. Percentage of respondents who provide training for each skill included in the survey are available in Table 2.4.

Table 2.4 Percentage of Respondents Providing Training for Specific PWC Skills

Skill	Percentage of Respondents (%)				
	Always	Almost Always	Sometimes	Rarely	Never
PWC Controls (Turning on/off, tilt/recline)	89.3	4.4	4.9	0.0	1.5
Charging and basic maintenance	77.8	12.3	3.0	3.6	3.5
Transfer to and from the wheelchair	79.0	11.7	7.3	0.5	1.5
Basic mobility (e.g., obstacles, turns, ramps)	88.7	7.4	3.0	0.0	1.0
Community mobility (e.g., curbs, potholes)	38.9	29.6	25.6	4.4	1.5
Driving etiquette (e.g., hallway, sidewalks)	55.2	18.7	15.8	8.9	1.5
Speed control (e.g., selection, control)	86.8	7.4	3.9	1.0	1.0
Incorporating PWCs into ADLs	34.8	28.9	22.6	10.8	2.9
Incorporating PWCs into IADLs	23.3	24.8	33.7	12.4	5.9
Public transportation (e.g., tie downs)	23.0	22.6	30.9	14.7	8.8
Personal transportation	21.8	20.3	30.2	17.8	9.9
Navigating (e.g., route planning)	33.2	22.8	27.2	11.4	5.5
Drive mode awareness and selection	74.4	16.3	7.4	1.0	1.0
Trouble shooting (e.g., disengaging motors)	58.8	19.6	12.8	6.4	2.5
Emergency procedures	52.7	26.6	12.3	5.9	2.5

2.3.2.3 Number and Length of Sessions

The number of training sessions provided varied by type of learner as shown in Table 2.5. For a new user with no previous wheelchair use, nearly half of respondents indicated they would

provide between 2 and 4 sessions. The majority of respondents provided between 2 and 4 sessions to new users who had previously used a manual wheelchair, experienced users with a new drive control, or experienced users with a new drive configuration. For experienced users receiving a new device with no additional changes to drive configuration or drive controls, 74.48% indicated they would provide 0 to 1 training sessions. Approximately 45% of respondents indicated their training sessions last between 40 and 60 minutes, while 41% of respondents indicated their training sessions last between 20 and 40 minutes.

Table 2.5 Number of Training Sessions by Type of Learner

	Number of Sessions				
	0-1	2-4	5-7	8-10	11+
Type of Learner	Percentage Respondents (%)				
New PWC user with no prior wheelchair use	8.2	**48.5**	21.4	13.3	8.7
New PWC user with previous MWC use	16.3	**54.6**	15.8	7.7	5.6
Experienced PWC user with new access method	17.4	**58.2**	19.0	3.8	1.6
Experienced PWC user; new drive configuration	42.1	**50.3**	5.6	2.1	0.0
Experienced PWC user; new chair	**74.5**	24.0	1.6	0.0	0.0

Abbreviations: PWC – powered wheelchair; MWC – manual wheelchair.

2.3.2.4 Training Techniques

The most commonly used training techniques (respondents indicated always or almost always used) were verbal cues (96.0%), visual cues (76.4%), trial-and-error (74.5%),

demonstration using the client's joystick (64.0%), limiting PWC functions (58.5%), breaking skills into steps (52.0%), and the use of an obstacle course (49.0%). The least commonly used training techniques (respondents indicated rarely or never used) were a driving simulator (93.4%), group or peer-based learning (84.4%), games (68.8%), and demonstration using a second wheelchair (60.8%). Hand over hand guidance was used "sometimes" by over half (56.5%) of respondents, while environmental modifications were used "sometimes" by just under half (48.7%) of respondents. Other training techniques identified by respondents in open-ended questions included the use of a large open area for general practice, practice within the client's environment, shared problem solving with the client, the use of a terrain park, repetition, and journaling,

2.3.2.5 Maintaining Safety in the Training Process

Nearly all respondents indicated they maintained safety through close physical proximity to the learner's wheelchair (97.4%). Limiting the environments where the learner is allowed to explore until the clinician feels the client is ready and adjusting programming parameters were also used frequently (89.7% and 80.0% respectively). A remote emergency stop was used by 27.7% of respondents. Other methods of maintaining safety for the learner, trainer, or others in the environment identified by respondents include restrictions on chair use (e.g., use only with supervision), the use of attendant control, patient education on road safety, and emergency stop procedures, and the use of steel toed boots by the trainer.

PWC programming parameters most commonly adjusted included speed (forward, reverse, and turning), acceleration and deceleration, sensitivity, and torque and power. Less frequently altered parameters included limiting the number of drive profiles, limiting driving to one direction only, tremor dampening, and joystick throw.

When asked what technologies or techniques would be helpful which the clinician did not currently have access to in an open-ended question, 27 respondents indicated the use of an emergency stop would enhance training safety. A dedicated simulated training course (n=7), and regular access to PWC programmers (n=5) were also identified as being useful to the training process.

2.3.2.6 Training and Cognitive Impairment

For clients who had cognitive impairments which may influence learning, most respondents indicated they would increase the number of training opportunities (88.5%), alter the training environment (72.4%), or alter the length of training sessions (56.3%); 46.4% of respondents indicated they would do all three. Approximately 40% indicated they would alter training in other ways including (in order of highest to lowest frequency of participant response), providing additional practice time with caregivers or assistants, providing visual cues, adjusting cues to match the cognitive level, breaking skills into smaller steps, assessing learning styles, training in the context of use, altering the programming, the use of repetition, the use of errorless learning techniques, and education of caregivers. Approximately 7% indicated they would not provide training to clients with a cognitive or memory impairment.

2.3.2.7 Barriers and Facilitators to Training

Respondents (n=40) reported barriers and facilitators to training when asked in open ended questions if there was any additional information they wished to share regarding their experience providing training PWC skills. Limited time (n=6) and funding (n=4) available for training were the most frequently reported barriers, in addition to limited education and practice for clinicians in PWC skills training (n=3). Furthermore, several respondents (n=7) indicated that the individual prescribing the chair was not the one providing training, therefore this

responsibility fell to another individual. Respondents indicated training in the natural environment (n=3), especially the client's home, in addition to client-centred practices where training is tailored to the individual's needs (n=8) would facilitate training.

2.4 Discussion

In this chapter, I described the results of two studies each aiming to develop a better understanding of the current practices of clinicians in delivering PWC skills training. Two themes we identified in the qualitative study underscore tensions between client-centred practice and resource availability, and tensions between providing training which meets the needs of the user, while also maintaining safety, particularly when clients experience challenges with cognition. These tensions are apparent in the survey results as well. Clinicians identify barriers to training including limited resources, which limit the available time for training, resulting in low training dose and intensity. Furthermore, there is often overlap between training techniques and techniques to maintain safety, which are seen clearly in how clinicians approach training for individuals with cognitive impairments.

The limited use of standardized or evidence-based programs is noted across both studies. While the Wheelchair Skills Program[101] was used most frequently by survey respondents, this may be influenced by the fact that the majority of respondents were Canadian, from jurisdictions where there have been substantial knowledge translation efforts of this program.[104,105] The PIDA was also noted to be used in open-ended questions about the use of training programs.[106] However, it should be noted that the PIDA is not a training program. It was developed as an assessment of PWC skill, therefore contains no specific suggestions regarding training approaches or progression of skill.[103] While the PIDA may be filling a need for some clinicians, they are adapting the assessment to guide training. Evidence-based approaches which address

training methods and approaches, and progressions specific to PWCs remain poorly addressed in the literature.

Considering training dose and intensity, the distribution of responses based on the type of wheelchair user (e.g., previous experience) suggests clinicians are interested in providing training which meets the needs of the user. However, because of limited resources, fewer training sessions are provided than are likely required by each of these user groups. This is closely related to the tension identified by clinicians of having a desire to engage in client-centred practice, while limited by resources available in terms of time (funding) and equipment. This ultimately has an impact on client safety. In a cross-sectional survey of over 200 PWC users, over 20% of respondents reported accidents in the previous year, and participants reported training was rarely provided.[29] This suggests that low levels of training may be associated with the potential for clients to experience accidents or injury.

It is clear that individuals may not be receiving the training the require. The low level of training is apparent in a recent study in a Canadian rehabilitation centre which found only 54.8% of individuals being discharged had received wheelchair skills training during admission.[87] Of those who did receive training, they received a median of 5 training sessions, averaging 30 minutes each. This training dose was also provided in a pan-Canadian randomized controlled trial which showed no statistically significant difference in PWC skills capacity between those who received wheelchair skills training using the Wheelchair Skills Program, and those who received standard care.[42] This suggests the effectiveness of the training dose provided may be not be well understood. A separate study comparing two training protocols describes different approaches; at the first facility, a three week/twelve session non-standardized protocol was delivered by occupational therapists and occupational therapy assistances, while the second

facility provided a two week/six session standardized protocol delivered by occupational therapists.[41] Investigation of outcomes between these two facilities found no statistically significant relationship between training intensity and PWC skill when controlling for facility differences.[41] Further research is needed to address the question of training dose and intensity.

The tension identified between maintaining safety and using training techniques which are most likely to promote learning is also apparent. Participants in the survey identified techniques for maintaining safety which were also identified by participants in the qualitative interviews, including simulating tasks, and starting in open spaces. The use of PWC programming parameters (e.g., max speed, power, acceleration) was also discussed by many participants. Clinicians often request PWCs be programmed at low torque and low power to ensure safety, however this does not provide a realistic driving experience, and may even hinder the development of certain skills including community mobility skills like navigating rough terrain. While the tension between safety and learning is clear when considering programming, it is equally evident in the choice of other training strategies. Clinicians must balance these trade-offs to maintain their client-centred focus, while ensuring safety for the client and others in the environment. Mortenson et al. identified this tension in his work developing overarching principles for inclusion on PWC guidelines in residential care.[27] They noted, "prescribers in long-term care settings therefore experience a tension resulting from their desire to facilitate independence while simultaneously ensuring safety for the users and those around them."[107(p21)] While the results of their Delphi study on overarching principles for inclusion in PWC guidelines in residential care suggest a general belief among prescribers, wheelchair users, and other stakeholders that some level of risk is reasonable, more in-depth training for PWC skills was

considered instrumental for increasing safety for people with cognitive, movement, and vision issues.[27]

Participants in both the interviews and the survey identified importance of learning in a real-world environment, rather than a simulated one, however the issue of risk to either the user or others in the environment is ever-present. This is clear across both of our studies – whether considering reluctance to allow someone with cognitive impairment to drive, or the reluctance to allow driving outside a training session. While taking away the chair between training sessions does not promote the functional development of skill, it is often used to maintain safety in the training process, a key tension identified in the qualitative study.

There are technological approaches which have been proposed to address the lack of time and available resources, while also addressing concerns with safety, including the use of driving simulators and virtual reality (VR) training. A recent systematic review found VR approaches demonstrated improvement in wheelchair outcomes following VR training, however none of the included studies compared VR training to clinician-led in-person training, and many did not assess transferability of skills to real-world environments.[108] Furthermore, the roles of VR and simulator technology have been questioned with respect to their ecological validity for training.[109,110] While these approaches show promise, more research is required to justify their widespread use in clinical settings.

2.4.1 Limitations

The studies described here have several limitations which may influence the results. The small regional sample in the qualitative interviews may reflect a specific experience in PWC training which is common to the region and may not be transferrable to other areas. However, the results are supported by complementary data from a larger North American sample in our

survey. Participants were also largely occupational therapists, and may not represent all practitioners, when one considers the range of professionals who may engage in PWC skills training. Furthermore, the self-report of training experiences may not reflect the reality of what happens in practice. Participants may be influenced by a social desirability bias in their responses,[111] or may overreport challenges in their practice in an effort to justify change to the systems in which they work, particularly given the primary interviewer was also a clinician from the same region. These challenges may also present themselves in the analyses, given the role of the primary researcher, however we have attempted to address these through the inclusion of additional interviewers, and the aforementioned trustworthiness strategies.

The survey may be limited by the size, geographic spread, and professional perspective of the sample. While we received responses from most jurisdictions in Canada and the USA, there was a much higher response rate from Canadian participants and may not be representative across North America. The survey was distributed through listservs and contact with relevant clinical organizations; therefore, we are unable to know the number of potential respondents. Furthermore, the use of a voluntary sample may introduce bias into the results, as those who participated in the survey may differ from those who did not. Finally, when considering hierarchical levels of evidence to demonstrate causality, cross-sectional research, including surveys, are generally considered to be of inferior quality.

2.5 Conclusion

Clinical practice in PWC training is largely driven by clinicians' desire to be client-centred, while clinicians struggle to meet the needs of their clients due to limited resources which constrain the time available for training, and the application of evidence-based approaches. Maintaining safety in the training process is a key concern for clinicians; however, they have

limited tools at their disposal to do so, which may influence the experience of training for the learner. Evidence-based training protocols using sound learning principles which are flexible enough to allow client-centred practice, with safety maintained in the learning process, are required.

Bridging Statement

In Chapter 2, we explored the current practices in powered wheelchair training in North America and identified gaps in the existing processes which could be addressed in a training program for individuals with limited cognition. In Chapter 3, we will provide information gathered during the course of qualitative interviews investigating the potential utility of shared control technology in the PWC training process. The data from both Chapter 2 and 3, in addition to further data described in Chapter 4, contributed to the development of a powered wheelchair skills training program, and the design of a clinical trial which will be evaluated in Chapter 5.

A version of Chapter 3 has been accepted for publication in the American Journal of Occupational Therapy.

Chapter 3: Development and Clinical Utility of a Shared Control Remote for Powered Wheelchair Skills Training

Wheelchairs are important means of mobility for many older adults living in residential care. In fact, approximately 50-55% of older adults in residential care require a wheelchair for mobility.[26,27] Responsibility for provision of the wheelchair typically falls to occupational therapists working within the environment, who must consider the needs of the individual, their physical and cognitive capacity, and features of the environment when selecting an appropriate type of mobility device for the individual. Once provided, the occupational therapist is also responsible for ensuring safe and effective use of the device through initial training, and ongoing monitoring. Throughout this process, the clinician must carefully weigh the needs and safety of the client with the safety of others in the environment. Concern for safety is often greater with powered wheelchair (PWC) provision than with manual wheelchair provision, owing to the potential to cause harm due to the weight and power of the device.

In Chapter 2, we discussed specific concerns clinicians experience when providing a PWC to an individual with cognitive impairments. First, clinicians are concerned about the impact of the cognitive impairment on the safety of the client, and others in the environment. As a result, those with cognitive impairments, may not be given the opportunity to demonstrate their potential abilities with PWCs.[37] Trainers may be hesitant to even engage in PWC training at all with these individuals due to concerns that they would not be able to respond effectively to safety issues within the training process.[27]

Second, clinicians are concerned individuals with cognitive impairment may not be able to learn the necessary skills. However, there is evidence to suggest this is not the case. Research

with individuals post-stroke, older adults in residential care, and individuals with developmental disabilities have all demonstrated at least some capacity for learning the required skills to operate a PWC.[33,41,112] However, methods traditionally used for training may not be adequate for individuals experiencing memory impairment. Training in PWC use is typically based on trial-and-error methods, where trainers identify errors made during a task and provide interventions to address difficulties or errors made by the learner.[113]For those with memory related cognitive impairments, trial-and-error may not be optimal as they are thought to interfere with the creation of memories for individuals who have difficulty forming explicit (knowledge-related) memory, including those with dementia.[54] Alternative approaches to training may allow clinicians to provide training more suited to their clients, and address the barriers in learning.

Technological approaches have been considered to address these challenges. Virtual reality-based simulators may help to decrease necessary clinician time and resource use, promote evidence-based approaches to training, and train clients in a safe manner, and there is potential for VR and simulators to complement existing training provided in a clinical setting.[110] A recent systematic review identified ten studies evaluating the use of VR for PWC skills training, each demonstrating an improvement in simulated wheelchair skills following the use of VR training.[108] However, there is little evidence to date on the transferability of those skills to real-world settings.[108] Archambault et al. hypothesized that differences in task performance between a real world setting and a virtual setting may be influenced by difficulty judging the distance between the PWC and obstacles, resulting in caution when approaching or navigating around obstacles.[109] Furthermore, much of the research to date has been conducted with cognitively well adults who in many cases are not wheelchair users,[108] and may not account for the specific needs of older adults with memory and other cognitive impairments, including impaired visuospatial

skills. While these systems address the challenges of maintaining safety there remains substantial work to be done to address the challenge of maintaining similarity to real world environments and incorporating adjustable and modifiable training methods for client's learning needs, including those with learning impairments.

To address the shortcomings of virtual reality and simulated learning for new PWC users with cognitive impairments, it is necessary to consider the challenges identified in Chapter 2 – maintaining safety and developing appropriate training techniques. To facilitate increasing complexity in the real-world, while maintaining safety for the learner and others in their environment, trainers required more control over the PWC during the training process. We developed a shared control teleoperation remote to support training, and address these specific concerns, with the intention of integrating the tool into a training approach guided by CLT and errorless learning approaches (discussed in Chapter 5).

Shared control is a teleoperation (remote) technology which allows simultaneous sharing of control between the PWC user (driver) and the clinician (trainer) without the need to switch between modes on the wheelchair. With the shared control remote, the trainer can override the PWC user's speed and direction as needed from up to 30ft away, as well as to perform emergency stop maneuvers, providing increased control to the trainer. Furthermore, data regarding driving behaviour (e.g., collisions and near-miss events) and interventions by the trainer (e.g., emergency stops or adjustments to speed and direction) could be collected electronically and used to inform training or prescription decisions. These features could change the dynamic between the trainer and the PWC user in the training and assessment process. Similar technology is used in vehicle driver training for cars and pilot training. For these devices, overriding controls of the driver provides opportunities for skill demonstration and reduces risk

by allowing the trainer to assist the learner when there is undue or unanticipated risk or difficulty. Despite the potential benefits of using shared control for PWC skills training this approach does not appear to have been addressed in the literature.

3.1 Objective

The objective of this study was to explore clinicians' perceptions about how a shared control remote teleoperation device for PWCs could be used in a clinical setting and to explore key features for the clinician interface (remote) for use during training.

3.2 Methods

We employed qualitative description design, with semi-structured interviews followed by thematic analyses, with a post-positivist paradigm.[93,94] The methodology and results are presented according to COREQ reporting standards.[95] This chapter includes data collected as part of a larger qualitative study to explore current practices in PWC skills training, the potential clinical utility for shared control technology within this process, and interface features to ensure the technology would be useful in clinical practice. In this chapter, I have reported only the content related to clinical utility and interface features of the shared control remote. Data regarding current practices in PWC skills training are described in Chapter 2.

3.2.1 Participants

Participant inclusion and exclusion criteria, and participant recruitment, are described in full in Chapter 2. Participants included occupational and physical therapists recruited purposively for a range of experience with various populations across practice areas.

3.2.2 Data Collection

We collected data over a series of up to 3 semi-structured interviews following an iterative technology development process (i.e., findings from each set of interviews were

incorporated into the technology prior to the next set of interviews). Each participant completed a minimum of one semi-structured interview focused on their current and past practices in PWC assessment and training (discussed in Chapter 2) and early feedback on a prototype shared control teleoperation device. We also introduced participants to a case-study to elicit specific examples of how the shared control device would be used in a clinical context.[114] Selected participants also completed up to two additional interviews focused solely on discussing clinical utility of the shared control device and providing feedback on the remote control interface. Interview guides were piloted and refined prior to starting the study and are available in Appendix A.

The first interview focused on the participant's perceptions of the utility of shared control technology. This interview was conducted in a location of the participant's choice, or by phone where necessary. We provided verbal explanation of shared control teleoperation, followed by questions regarding perceptions of the technology based solely on the description, and discussion of the use of shared control with a case-study. We also gave participants the opportunity to use low-fidelity prototyping materials (i.e., clay, interlocking building blocks, paper) to provide insight into the look and feel of their ideal clinical interface.[115] A minimum of two weeks following the initial interview (no longer than four weeks), we conducted a second interview with a subset of participants (n=10) including an opportunity to observe operation of the device and experience driving the PWC using a prototype shared control remote. Due to constraints with moving the PWC to locations outside of the city, participants were included for the second interview if they were able to attend the in-person observation/experience to provide feedback. This interview was conducted in our research facility at GF Strong Rehabilitation Centre. We used open-ended questions to elicit perceptions of the prototype and explore the potential use of

the technology in practice, with reference to the case study introduced in the first interview. Examples of potential interface devices (remotes) were provided in the second interview to elicit further feedback on the look and feel of the interface, and to guide the selection of the appropriate remote control for the prototype CoPILOT system.

We provided a subset of participants who completed the second interview (n=5) with an opportunity to complete an additional (third) interview to provide feedback on development of the shared control remote interface approximately two months following the second interview. In this interview, participants experienced driving the PWC with a redesigned remote control, based on the feedback gathered from the initial two interviews. This interview was focused on the benefits and drawbacks of the shared control device during use and on mapping of the controls to suit the needs of the trainer. The third interview was conducted at an engineering lab at the University of British Columbia. Following the third interview, the remote was further refined based on this feedback (see Appendix D for images and mapping of the remote controls at each stage).

A clinician experienced in PWC provision and conducting qualitative research (EMS), including semi-structured interviews, an engineer with experience in usability testing and product development strategies (SR), and a computer scientist with experience with robotic operating systems applied to PWCs (TJ) conducted the first and second interviews. This provided both clinical and technological perspectives, including opportunities to challenge assumptions from those familiar with either the clinical or technical requirements for the device. The third interview was conducted by the clinician (EMS), with input on request from a computer scientist responsible for mapping the controls to the remote. All interviewers were female.

3.2.3 Analyses

Interviews were audio recorded and transcribed verbatim, and we performed line-by-line coding with each document (all rounds of interviews). While an initial review of the interview transcripts was completed by the engineer and computer scientist to identify features for integration into the subsequent prototype, full analyses of the clinical utility data, including the use of specific interface features for clinical applications was completed following the culmination of all rounds of interviewing. Analyses were guided by Braun and Clarke's six phase framework for thematic qualitative analyses.[94] Codes were developed independently by two investigators (ES and SR) using an inductive process from the interview transcripts from all three rounds of interviews. Initial codes were grouped into preliminary categories, discussed by two investigators (ES and SR), and revised in three subsequent rounds of coding. We then re-evaluated preliminary categories to ensure consistency with the data and address overlap, then aggregated into themes with the assistance of a fourth investigator (WBM). Final themes were reviewed to ensure they were exclusive and represented conceptual areas related to the clinical utility of PWC shared control. The analyses are also described in full in Chapter 2.

3.2.4 Trustworthiness

To support trustworthiness of the data and analysis, we used strategies including triangulation of informants, and reflexive discussion between interviewers.[98] Triangulation of participants and investigators included engaging informants from multiple practice settings and client populations through purposive sampling,[97] using multiple interviews in an iterative process,[97] and conducting frequent debriefing between interviewers and with a supervisor. Interpretation was guided by my experience as an occupational therapist with experience in the field[116] and an alternative perspective from an engineer working outside the clinical field who

could question assumptions made during the data collection and analyses. Reflexive discussion between interviewers allowed us to question our own assumptions of the potential utility and technological requirements, and ensure results were not guided by a single perspective. It also provided an opportunity to understand the differing clinical and technical perspectives of the interviewers, and how these contributed to our understanding of the results. We approached the interviews with specific assumptions. Specifically, we had an assumption that clinicians would find the technology to be useful to their practice, however would be hesitant about incorporating it. Furthermore, we had an expectation that younger clinicians and those with video gaming experience would have a more positive experience. We also anticipated participants would be interested in the use of a smartphone based solution. As we were optimistic about the potential of the new technology, the guides were created and piloted to avoid leading questions in the interviews and probed for cases that diverged from our expected outcomes. To address the potential impact of my familiarity with the culture of the participants, I used reflexive discussion to establish a mutual understanding of the data, establish common language, and we have both convergent and divergent data in our reporting. While there is some expectation of subjectivity within qualitative data analysis, reflexive discussion helps to limit the potential of undue influence of a single perspective.[98]

3.3 Results

3.3.1 Participant Demographics

As reported in Table 2.1, 15 clinicians participated in the interviews (10 of these individuals participated in the second interview, and 5 in the third interview). The majority were female (n=12), occupational therapists (n=14), with clinical experience ranging from less than five to more than twenty years. Participants worked in a range of practice environments and

approximately half worked in residential care. Areas of practice varied, including neurology (n=1), adult general practice (n=2), older adults (n=8), acquired brain injury (n=2), spinal cord injury (n=1), and developmental disabilities (n=1).

3.3.2 Thematic Analyses

Our analyses identified three overarching themes. The first, "a big enabler," described how shared control provides opportunities to train individuals who may otherwise be denied access to a PWC. It included three sub-themes (*italicized in the text below*): reducing training associated risk; enabling alternative training and assessment approaches; and necessary clinician training and practice. The second theme, "changing the learner experience," described how shared control may promote success in skill development by changing the learning experience. This theme has four sub-themes (*italicized in the text below*): reducing anxiety, stress, and frustration; building confidence through success, changing the training relationship; and mitigating drawbacks to shared control. The third theme, "focus on the client, not on the device," described the clinicians' desire to be able to focus their training attention on the client's learning, rather than on their own capacity to use the shared control device. This theme has two subthemes *(italicized in the text below)*: intuitive to use; and as simple as possible.

3.3.2.1 A Big Enabler

All participants felt shared control technology would provide new opportunities for clients and trainers in the assessment and training process. One of the benefits described by participants was the potential for the technology to be "a big enabler," giving people who might not otherwise be afforded the opportunity a chance to try it. Natalie, an occupational therapist (OT) with considerable experience working with older adults in a residential care setting, described this challenge:

> There are people we write off pretty quickly. They can't see well enough, they don't have enough… discrete control, they can't stop… I think it would enable a population of people that you would be afraid to … give an opportunity [to try a PWC].

Caitlin another experienced OT working in residential care described how this opportunity may give the learner a better understanding of their own capabilities, when mentioning that, "[shared control would be able to] give them [new PWC users] the ability to just try it out. They might even realize themselves that it's just not a good idea." Thus, she suggested that both trainers and new PWC users may benefit from learning more about the PWC user's driving capabilities.

3.3.2.1.1 Reduce Training Associated Risk

All participants described the potential of the shared control remote to *reduce training associated risk* for the PWC user, the trainer, and others in the environment. This was summarized by Rebecca, an OT with experience with older adults living in the community, who noted, "I always struggle with assessing people in a crowded situation. Because I need to know they're safe… but in order to figure out if they're safe, I have to potentially put people at risk." The opportunity to reduce risk for multiple stakeholders was identified as a primary positive outcome of the use of the shared control technology. Related to reduction in risk, all the participants interviewed thought the shared control remote would allow them to provide training in more complex, real environments, earlier in the training process. As Natalie described:

> … it would be beautiful in the summer time, and I'm a little uncomfortable with them going somewhere, and [we] stick indoors. But wouldn't it be nice to be able to go outside? ... [Then it would be possible to]…progress somebody into more real world a bit quicker, and then be able to really start to see what they are capable of.

Roger, a community OT working with adults, described how shared control technology might help address the challenging realities he encounters during training and assessment. He said, "Getting into busier environments with noises and bright lights and dogs that bark, and all that kind of stuff, that's the meat and potatoes of life, right? So I can really see how someone is doing with those extra challenges." Rebecca also noted the benefits of practicing in a real environment:

> Right now, I do that [simulated crowded or busy environment] with a lot of dining room tables and chairs. Which is not the same thing as little old ladies and walkers. People react differently…people aren't chairs, they move, they're unpredictable.

For these participants working in the community, without access to 'safe' learning spaces, complex environments were a daily reality. Jennifer, an OT working in acquired brain injury in community care addressed the challenges she faced:

> I don't really have a choice [about where to train someone]. I've done a little bit in their foyer and in their driveway or whatever it is that we have, but then we have to venture out, and we have to deal with these busy areas, so that would certainly make it easier. I think that would give both myself and the client more confidence.

Increasing confidence for the trainer and the learner was also identified as part of the theme "Changing the Learner Experience".

3.3.2.1.2 Enable Alternative Training and Assessment Approaches

Various features of the technology were perceived to *enable alternative training and assessment approaches*. Two thirds of participants described how being able to get further away from the client, or to be able to observe the client from a different perspective, would be beneficial for their assessment and training processes, while still allowing the trainer to maintain safety. Roger indicated it would be helpful to gather additional information about the client's

driving capabilities by seeing the client from a different perspective. He noted, "…I am rarely in front of the chair when [the client is] operating but being in front of the chair gives me a good sense of where they're looking… and what they're attending to. That gives me a lot of information." The capacity to be further away from the chair also provided him an opportunity to, "… get an understanding of what the client might do if you weren't around," an opportunity which he indicated was rarely afforded in traditional PWC assessments.

Participants discussed the potential for the technology to enable training approaches, which are not possible without remote override or operation. For example, trainers could use the technology to teach specific skills using collaborative training techniques. Natalie shared a specific example of how the shared control remote could be used to train a PWC user to navigate an elevator, "Let's say a person is lining themselves [up] to go in [to an elevator]. I could move the joystick a little bit, I could give a verbal prompt… and then the person could successfully navigate, rather than having to totally take over for them." Caitlin, an OT working in residential care, discussed the benefit of being able to provide sequential learning experiences, where, "… in the beginning stages, maybe it's just better that they get used to a chair and not have to worry about a collision." The complexity of the tasks required of the client could then increase over time, while allowing the learner to stay in a familiar environment, rather than grading the complexity of the task using simplified or simulated environments. Other participants spoke about the opportunity to demonstrate challenging tasks to allow the client to feel the correct movement.

Participants identified opportunities to use data, which could be collected by the technology during the training and assessment process, to inform their assessment and justify their clinical decisions. Rebecca noted, "it might be useful to see how many times I have to

assume control. Then that could be useful, especially in justifying to [residential care] facilities that this person can… learn, can use their power wheelchair." The data provided by the shared control system could potentially be provided to the clinician in a way which might demonstrate improvement over time. Elizabeth, an OT in residential care who indicated she was often hesitant to trial clients with a PWC said, "[This data] would impact me. Maybe there [would be] more people in a chair that I would try than otherwise. People who I had more doubts about…" Having access to the data collected was seen as a starting point for intervention and education. Chris, an OT working in inpatient rehabilitation, thought it, "… might provide me with more information to make adjustments to the chair," speaking to a strategy he commonly employs of adjusting programming parameters to match the client's abilities to ensure safe and successful driving experiences in the early stages of learning.

3.3.2.1.3 Necessary Clinician Training and Practice

For shared control technology to provide benefits in a clinical environment, participants also stressed the fact there would be a *necessity for training and practice for the clinician* to operate the controller successfully. Following an experience using the prototype device, one participant noted it was, "… a bit nerve wracking when I was trying to control it." This was particularly true for participants who were less familiar with remote controlled and video game technologies. Chris, who had substantial experience with joystick-based gaming, said, "I have more familiarity with the … controller than some clinicians, so I think that puts me at more of an advantage. I don't really have to look at the controller to know what I'm pressing." Jillian, who had less related experience, noted, "I would need to work with it fairly regularly to be comfortable enough to… be in a crowd… and be confident that I could control the chair for

them. I think it would take a bit of practice on my part." All participants identified training and practice as a strategy to mitigate the challenge of working with a novel technology.

3.3.2.2 Changing the Learner Experience

3.3.2.2.1 Reduce Training-Related Anxiety, Stress, and Frustration

Most participants anticipated the positive impact a shared control device could have on a client's psychological state during training. Eleven of the 15 participants described the potential for the technology to *reduce training-related anxiety, stress, and frustration* for both the learner and the trainer. Anxiety was perceived as having a negative impact on learning. Jennifer, a community OT working with individuals with acquired brain injury, noted, "People don't learn well when they're anxious or have panic and things aren't going well." Elizabeth, who worked with older adults, described being able to provide an opportunity for their, "… mind [to be] in a state of being able to take in information." For those clients who were intimidated by the prospect of using a PWC, Chris thought a reduction in stress might, "make clients maybe a bit more willing to learn… knowing that I have control of the chair at all times." Natalie elaborated on this, describing the experience of an older adult PWC user with no previous experience with the device:

> There is all this new learning and so it's frightening… and then you have a bad, bad bump, and then they don't want to do it anymore. Or it gets disheartening or frustrating. And so, because you … can't get out of their room, you can't get to the places where they want to be. The total time that they are in the chair, they have not had any success.

These unsuccessful experiences were seen to be detrimental to learner progress and motivation, which might impact training outcomes.

3.3.2.2.2 Building Confidence Through Success

All but three of the participants described how shared control technology could help to *build confidence through successful experiences*, which may promote learning. Jennifer focused on the importance of success in learning, stating, "If we don't have success then… we can't move onward from where we are, right? Because you just keep having failure, and failure, and failure, and so how do you get to that point where you start demonstrating some success?" Success was seen as promoting engagement in training, with participants noting the technology would allow them to take more managed risks. Agnes, an OT working in residential care, felt this was important to maintaining engagement because, "… with more risk always comes more reward… and if… there's' this perceived risk, and they're successful, then they're willing to continue to try, and to stay engaged in the process." Sarah, who also worked in residential care, noted, "if you can make those things of what could be considered a difficulty skill easier, successful, then the confidence is built sooner. And I think that's a big part of successful wheelchair training, is the client developing the confidence to do it." While participants did describe opportunities to build confidence, Agnes noted the potential for a client to develop, "…way more confidence than they should have," from training in a reduced risk environment.

Confidence was not only related to the client's experiences but also to the trainer's own confidence and willingness to engage in training. Jillian noted, the technology, "… would just give confidence, really, to both me and the person I was training. I think it could give a little bit more confidence with that process of… reducing the risk of harm…" Increased confidence for both the trainer and the learner was identified as having potential to change training outcomes.

3.3.2.2.3 Changing the Training Relationship

Shared control technology was seen as an opportunity to *change the relationship between the clinician and the client*. Natalie felt this could be accomplished through allowing the trainer,

"To still be there and support them but [give] them a little more room." Rebecca described how the device would allow them to, "… walk beside her [the client] and have a more normal relationship with somebody in a wheelchair." While Jillian described situations where their client might be stuck in a tight space, and how the device would allow them to come to their aid, "It would help… maintain the dignity within the process." Most participants felt the change in the nature of the relationship could have a resultant positive impact on learning.

3.3.2.2.4 Mitigating Drawbacks to Shared Control

Participants also identified the importance of *mitigating drawbacks to using shared control*, including the client's potential difficulty understanding the behaviour of the chair when the trainer was overriding. Chris questioned whether:

> … they are going to necessarily make that correlation between them [the chair's action and the trainer's input], or are they just going to do it the same way the next time because that's what they did [when the chair produced that action]? How are they going to be able to relate what the therapist is doing to what they [the client] are doing?

Eleanor, an experienced OT in residential care said, "…if they thought they were going this way, when all of a sudden they're going some other way, they wouldn't want to learn. They would need some good feedback on why that's happening." Participants stressed the importance of communication and feedback between the trainer and the client to mitigate this drawback. Challenges providing feedback to the client represent potential limitations to the technology.

Two participants who worked in the community described the importance of preventing reliance on the shared control system when trying to develop independent driving skills. Specifically, it would be important to consider when to wean the client off the assistance very carefully. As Jennifer said, "… if a person feels some sense of security with me being there,

well, I'm not going to be there once the chair's delivered." Rebecca indicated, "It would be easy to take too much control away from the client. The therapist would have to really be aware … to let the client get to the point where they are correcting their own mistakes." The perceived need to allow the client to make mistakes was the most commonly cited concern by participants.

3.3.2.3 Focus on the Client, Not on the Device

In addition to discussing the potential uses, benefits, and drawbacks of the shared control technology, participants also had the opportunity to provide feedback on the look and feel of the shared control interface (remote), and its optimal operation.

3.3.2.3.1 Intuitive to Use

All clinicians stressed the importance of ensuring the device was *intuitive to use* as this was critical to the training success. Rebecca, an occupational therapist working with older adults in residential care explained, "I don't want to be concentrating on what's going on in my hand… I like it just to stay where it should and always have the buttons. I know I am not going to have to reach for them." Chris echoed this concern and explained a physical remote would be preferable to a cellphone app based remote due to concerns he would need to be "totally concentrating on this thing, because I want to concentrate on what's going on with the client." As a result, Chris felt a joystick would be "much more intuitive than learning a new control, because a lot of us have driven a powered wheelchair with a joystick before." All participants expressed their preference for a handheld remote control with a joystick, rather than a cell phone app.

3.3.2.3.2 As Simple as Possible

The concerns with how intuitive the controls would be were dovetailed with the desire to keep the device *as simple as possible*. Jillian, an occupational therapist working in residential care expressed concern about the potential complexity of the device, stating "I just feel like

keeping it simple would be a lot easier to remember what control does what." The primary controls requested were the ability to control speed and direction of driving, and the remove emergency stop function. The emergency stop was seen by Jennifer, a community OT as being particularly important to be "something easy that I'm not going to hit at other times, just something really easy." The primary interface concern expressed was that the device be able to fit in one hand. Eleanor, an experienced OT working in residential care summed this up nicely, by stating "I like having one hand free. I'm also trying to interface with a resident, so I think something simpler and smaller the better." When presented with three off-the-shelf remotes from gaming manufacturers as potential options in the second interview, all but one participant preferred a single handed remote with a thumb joystick. These subthemes illustrate the importance of simplicity and ease of use for adoption of new technology in their clinical environments.

3.4 Discussion

Overall, clinicians were generally positive about the potential use of shared control for PWC skills training. There were suggestions shared control could facilitate training for a wider range of individuals by reducing risk and enabling alternative approaches. This would help to change the experience of the learner to provide a more successful, positive experience. However, clinicians shared concerns about potential drawbacks to the use of shared control, as well as their specific interface needs. The discussion below is organized by theme.

3.4.1 A Big Enabler

This theme explored the ways shared control may enable learners to participate in PWC skill training who had not previously been given the opportunity, through reduction of risk, and alternative training approaches. This is particularly important when considering those

populations who may otherwise not be given the opportunity for training. Individuals with cognitive impairments may be denied access to a PWC based on a presumed inability to learn or to drive competently. In residential care, as many as one in two residents require a wheelchair for daily mobility,[26] and cognitive impairments associated with dementia impact 56% of individuals over the age of 80.[117] Given the number of people with cognitive impairments living in residential care,[117] it is reasonable to assume many of those who require a wheelchair for mobility also experience some cognitive impairment. For many of these individuals, a manual wheelchair is provided, however for those who are unable to use the manual wheelchair effectively, this can be considered a form of restraint.[118] Shared control may facilitate the opportunity to try a PWC for individuals who experience both mobility and cognitive impairment.

Reducing risk in the learning environment also enables learning as it increases the potential learning experiences an individual might have throughout the training process. Learning to drive a PWC is not without risk, due to challenges in the client's environment.[27] Safety is frequently maintained through proximity of the trainer, who may intervene by removing the user's hand from the joystick or turning off the chair.[101] This proximity can be difficult to maintain in tight environments or at higher speeds. In addition, learners rarely experience driving without a trainer nearby, until the trainer is confident in their abilities. Therefore, training may not adequately prepare clients for an independent driving experience. Shared control may help to ensure safety in the assessment and training process and permit a more in-depth understanding of a user's capabilities.

This reduction in risk also enables learning in more natural environments, where clinicians may have previously been hesitant to provide training. When learning procedural skills

(i.e., how to complete a task), there is evidence that transfer of learning to new environments may be difficult for individuals with Alzheimer disease or related dementias.[119] Therefore, learning in the environment where the skill will be used, rather than simplified or simulated environments, may be important for success.[62] Shared control can facilitate safe opportunities to increase complexity within an ecologically valid environment.

There are also training techniques which can be used to facilitate learning for those who have cognitive impairments. Reducing error during learning through errorless learning strategies including modelling, cued learning, forward and backward chaining (i.e., trainer and learner each complete specific steps of the skill, adding steps in a forward or backwards approach until learner is completing whole skill), and spaced retrieval, may facilitate procedural learning for these individuals.[120,121] Advances in technology provide an opportunity to explore the potential for errorless training through training protocols more suited to their learning needs.

Shared control may provide opportunities for these alternative training approaches. Clinicians identified the potential for skill demonstration, using chaining approaches to reduce complexity, or grading the difficulty of the task over time. These approaches could provide substantial benefit to the learner by modifying the learning experience, and are well aligned with the principles of errorless learning, which suggests training experiences where the learner is cued or directed towards the correct response or outcome can produce successful outcomes over time through implicit learning processes.[120] Errorless learning has been shown in a recent literature review to have beneficial effects on learning procedural skills (e.g., use of technology, route planning, activities of daily living) in individuals with mild cognitive impairment and dementia.[122] Many of the techniques used in errorless learning techniques (e.g., modelling and demonstration, cueing to the correct response, stepwise, graded, or chained learning) focus on

providing successful experiences of task completion and are similar to alternative training approaches identified by the participants.[122] Therefore, there may be a potential clinical role for shared control in facilitating errorless learning approaches.

3.4.2 Change the Learner Experience

Clinical outcomes in PWC skills training are also likely to be influenced by the experience of the client throughout the training process. Clinicians identified this when describing how experiences of anxiety, stress, and frustration associated with learning a new skill may impair learning. Studies have shown that anxiety interferes with processing effectiveness and retention, both of which are required for successful learning.[123,124] Shared control may enable a reduction in training associated anxiety and frustration, while providing opportunities for success, using errorless training techniques.

It is important to consider the potential drawbacks to shared control which were raised as well. Clinicians were concerned about learners developing dependence on the device and being unable to transition to independent driving following the training. We can draw parallels between this concern and recent research on the use of semi-autonomous driving systems. In a study investigating reaction time for drivers of semi-autonomous vehicles, reaction time increased with greater time disengaged from the task of driving, regardless of how engaged the driver was cognitively in the task.[125] Further research on the use of automated navigational aids suggests reliance on these systems can impair the acquisition of spatial knowledge during a navigation task.[126] We may experience similar challenges with the implementation of shared control for training PWC users, therefore these concerns are worthy of due consideration, including future evaluation of the best ways to withdraw support and ensure the development of independent driving skill.

Clinicians' concerns regarding the challenges providing targeted feedback could be addressed using haptic guidance (i.e., providing corrective feedback using vibration or movements) built into the wheelchair joystick. Two studies exploring the influence of haptic guidance on learning steering tasks found that haptic guidance provided as needed had the potential to both reduce errors in the learning process, produce better motor learning outcomes than guidance provided all the time, and improve retention of steering skills over time.[127,128] Future studies considering errorless approaches might consider the addition of haptic guidance to the learner's joystick in the shared control system.

3.4.3 Focus on the Client, Not on the Device

One further potential barrier to the adoption of shared control as a training tool is the challenge of introducing new technologies into a clinical setting. While participants were positive about the potential utility of shared control in training, the familiarization of the trainer with the technology will be important to provide competent care. A recent study of technology use and acceptance in rehabilitation found that clinicians were more likely to adopt technologies that enhanced their job performance or client's outcomes.[129] These factors may override the concerns associated with learning and training on the new technology. Clinicians all spoke about the importance of simplicity and intuitive/easy use of the technology. Models of technology adoption, such as the Model of Technology Acceptance and the expanded Unified Theory of Acceptance and Use of Technology (UTAUT) both include concepts of ease of use as critical factors contributing to technology adoption.[130,131] Intention to use may also be influenced by perceived usefulness (described in this study as clinical utility), as well as social influences and facilitating conditions in the environment.[131] Future research focused on the efficacy of shared control in a clinical setting, as well as client and clinician perspectives of the technology, will

provide evidence about the use of shared control as an assessment and training tool for PWC users and increase the likelihood of adoption. This will also be addressed in the feasibility study discussed in Chapter 5.

3.4.4 Strengths and Limitations

A primary strength of this study was the process of co-creation with the intended user group (clinicians), serving as a form of integrated knowledge translation. Furthermore, conducting the study using a transdisciplinary approach, allowed involvement of collaborators from multiple disciplines to achieve a common goal based on a common understanding of the problem. Following the establishment of shared language, trust, and open communication, this allowed us to challenge discipline specific assumptions, and facilitate implementation into the clinical setting. These approaches are consistent with principles for fostering transdisciplinary development of assistive technologies, guidance for creating technologies with real world impact which attempt to solve complex problems.[132]

There are three main potential limitations to this study. First, the findings represent only the perceived clinical utility of the technology, and the use of a prototype. Providing an opportunity for clinicians to use the device in practice may elicit further thoughts about the utility of the device in a real-world environment. Second, we collected data from participants in one region who work within similar health systems, structures, and policies. This may result in the findings being influenced by these experiences. Finally, the interpretation of the data was influenced by the experience and expectations of the investigators, in addition to our research knowledge. As a clinician, my experience in clinical settings may have contributed to an expectation of low levels of training, limited use of evidence-based tools, and barriers of time and resources. Strategies to enhance trustworthiness of the data and analyses were used,

including collaboration between a clinician and an engineer to minimize the discipline specific perspective, including identifying complementary understanding. Sampling for maximum variation addressed concerns with sample size and transferability of the research by ensuring participants represented a range of experience.

3.5 Conclusion

Shared control may have the potential to broaden the scope of therapeutic intervention by reducing risk and facilitating alternative training approaches. Participants identified the potential for positive psychological impacts on learning, practical implications on the training process, and potential risks of device use. There is a need to investigate shared control technology in practice to address both outcomes associated with training and client and clinician perceptions of the shared control technology. Furthermore, future development of shared control technologies would benefit from consideration of integrated feedback mechanisms to promote learning, including the inclusion of haptic feedback provided as needed.

Bridging Statement

In Chapter 2, we identified specific gaps in clinical practice – notably the limited use of evidence based PWC skills training programs. In Chapter 3, we confirmed support for a shared control teleoperation system to be used for training, particularly the potential use for training techniques which might be more suited to providing successful, safe learning experiences for new PWC users. However, there is no published evidence on the task demands of PWC driving from which to build a training program. Chapter 4 describes an evidence-based approach to understanding the task demands of PWC driving, to be applied to the development of an evidence based, errorless driver training program facilitated by shared control technology (described and evaluated in Chapter 5).

Chapter 4: Task Demands for Powered Wheelchair Driving

There is limited evidence to draw from when developing a powered wheelchair (PWC) skills training program. Multiple studies have explored the key components and demands of manual wheelchair use, including the necessary skills to complete a wheelie and motor skills required for wheelchair propulsion.[44–46,133–135] These have contributed to evidence-based approaches focused on the application of motor learning principles for fundamental skills training, such as the Wheelchair Skills Program.[43] However, simply applying those principles to PWC use has several challenges associated. Primarily, there are a range of options to control a PWC, including the use of joysticks, sip and puff, and switch arrays, which rely far less on motor control, and therefore may be less conducive to training using the principles of motor learning. PWCs also lack the agility of manual wheelchairs, and execution of specific skills (e.g., curb climbing) are more related to the capabilities of the chair than the skills of the user.

The developing evidence demonstrates the associations between cognitive processing, visual and visuospatial skills, and problem solving with frequency of PWC use.[47,48] Clinicians often use this limited research, or research in motor vehicle driving, to assume the skill requirements for PWC use, however existing training programs do not address these complex skills. There is a gap in the literature addressing the analysis of the skills used regularly by PWC users. One possible method to address this gap in our knowledge is using task analysis, allowing us a more concrete understanding of the skills used to complete a variety of PWC skills.

Task or activity analysis is a fundamental skill used in the development of interventions in rehabilitation, allowing clinicians to analyse and break down a task in a systematic way.[8] Task analysis consists of the development of a set of steps required to complete the task, and the skills,

abilities, and knowledge used.[70] A thorough task analysis allows the clinician to build progressive or graded interventions which match an individual's strengths and limitations.[8] In addition, they contribute to the ability to modify tasks to suit a learner's needs, and provide forward and backward chaining interventions.[1] Understanding of the skills, abilities, and knowledge used in completion of a task contributes to a clinician's reasoning and evaluation process, and helps to determine whether an individual will be able to acquire certain skills.[70]

In order to complete a task analysis, the clinician must select a task to be analysed, establish the criterion by which they will know the task has been completed, then consider the steps they or another user would take to complete the task, and the motor, cognitive, and perceptual processes they would engage in order to complete each step.[8,70] For many activities of daily living, the focus for the task analysis is determined by the 'typical' completion of the task based on the clinician's experience. However, for the tasks required for PWC driving, the clinician often does not have the experience required to fully analyse the steps for each task, nor the cognitive, motor, or sensory functions required.

To complete a thorough task analysis, it is ideal to engage the individuals for whom the task is a daily experience, in this case, experienced PWC users.[70] However, given the focus on developing a training program, it is also important to included perspectives from expert clinicians perspectives as they may be able to provide insights about training across a wide range of clients or populations which may not be well understood by the experienced PWC users.

4.1 Objective

The objective of this study was to engage experienced PWC users and expert clinicians to systematically explore the task demands of indoor PWC use, including frequently used skills, abilities, and knowledge.

4.2 Methods

This study employed the use of a post-positivist approach to qualitative description and a combination of directed and conventional content analysis,[93,100] drawing from concurrent and retrospective think-aloud methods to complete a task-analysis. Task-analysis is a reasoning process used in rehabilitation sciences, specifically occupational therapy, for skill instruction.[70] Think-aloud approaches are drawn from the fields of education, psychology, and usability testing in technology development, where they are commonly used to understand the cognitive processes required for a task.[136,137] As we are focused on understanding the processes required for PWC use, this approach, combined with a task analysis, was ideal. The methodology and results are reported according to COREQ standards for reporting qualitative research.[95]

4.2.1.1 Think-Aloud Methodology

A think-aloud approach is a method to collect information on cognitive processes, specifically tasks requiring problem solving.[9] This approach is often used for procedural tasks which may have specific skills which are not known through other sources,[138] including reasoning processes used by clients and patients during tasks.[9] A think-aloud approach requires the individual to verbalize thoughts which would typically occur consciously, and bring forward unconscious decisions to consciousness during the completion of a task. This allows the observer or researcher to gain an understanding of the thought processes ongoing throughout task engagement, including decision making and cognitive processes.[9] Think-aloud methods may be

conducted concurrently or retrospectively. Concurrent methods provide an unbiased account of ongoing thoughts, however may suffer from interruption during task completion.[138] Retrospective methods may provide a more complete analysis; however, they are subject to memory degradation and reorganization, and may provide a false or biased account of the ongoing thought processes.[138] Combined methods can be used to gain the benefit of both– where the information gleaned in the concurrent think-aloud is used to facilitate a retrospective method immediately afterwards.[138] Ideally the retrospective think-aloud is completed immediately following the concurrent data collection. Therefore, we have used a combination of both retrospective and concurrent think-aloud for this study to develop a more robust understanding of the skills, abilities, and knowledge used in PWC driving.

4.2.2 Task Selection

To reduce burden on participants, while ensuring breadth in the analyses, we selected seven indoor driving tasks for analyses, including driving 100m in a straight line and stopping on command, turning 90 degrees moving forwards (left and right), turning 90° moving backwards (left and right), getting through a hinged door (both directions), manipulating in a congested area, navigating an elevator, and parking at a table. These tasks are representative of common requirements for indoor use of a PWC, and are of sufficient complexity to require cognitive processing to complete, a key feature of tasks suited to be evaluated using think-aloud methods.[138] They were identified using two assessments commonly used for indoor PWC use – the Wheelchair Skills Test for Powered Wheelchair Users (WST-P 4.2),[43] and the Power Mobility Indoor Driving Assessment (PIDA).[103] While there is limited literature on PWC assessments, there is support in the literature for the validity of both the WST-P and PIDA for assessing PWC driving.[103,139] A review of assessments addressing wheelchair activity and

participation identified only one other potential test for PWC users– the Obstacle Course Assessment for Wheelchair User Performance (OCAWUP).[140] As it was neither commonly used in published clinical trials, nor identified by clinicians as contributing to PWC skills training, in our survey (Chapter 2) it was not included.

Commonalities between WST-P and PIDA were initially identified to select potential tasks for inclusion. Following this, tasks which formed smaller components of larger tasks (e.g., rolling forwards 10m vs driving 100 m, avoiding moving obstacles vs. manipulating in a congested area), those which were not driving related (e.g., turning the wheelchair on and off, operating body positioning options), or which are typically encountered in outdoor environments (e.g., ascending/descending a 5cm curb, getting over a gap) were removed. Criterion for task completion for each of the seven tasks can be seen in Table 4.1.

Table 4.1 Task Criterion for Indoor Driving Tasks

Task	Source	Criterion
1. Driving 100m in a straight line and stopping on command,	WST-P 4.2	User moves the wheelchair in a forward direction 100m, without bumping into any item or person. User stops the wheelchair within 1m following a stop command.
2. Turning 90 degrees moving forwards (left and right),	WST-P 4.2 and PIDA	User approaches and completes the 90 degree turn with sufficient space to complete the task without contact with a person or object.
3. Turns 90m moving backwards (left and right),	WST-P 4.2	As for above, moving backwards. User should observe behind them during task.
4. Getting through a hinged door (both directions),	WST-P 4.2	User opens, moves through door, and closes door behind them independently.
5. Manipulating in a congested area,	PIDA	User moves a minimum of 20m through a busy area including individuals moving around, and stationary obstacles.
6. Navigating an elevator,	PIDA	User enters, spaces within, and exits the elevator safely, and without contact with others or the elevator walls.
7. Parking at a table.	PIDA	User parks in 1m space between a person and table leg without knocking the person or table.

Abbreviations: WST-P 4.2: Wheelchair Skills Test for Powered Wheelchair Users version 4.2; PIDA: Power Mobility Indoor Driving Assessment

4.2.3 Participants

Participants (n=10) were recruited purposively to provide maximum theoretical variation in responses. We recruited a volunteer sample through personal networks of the research team. Two categories of participants were included. The first included individuals who were experienced PWC users (WCU, n=5), with a minimum of six months full time driving experience using a joystick driven PWC. The second included expert clinicians (EC; occupational or physical therapists, rehabilitation assistants, or assistive technology professionals, n=5), with a minimum of 5 or more years of PWC training experience. A mix of WCUs and ECs was used to provide context and understanding on the processes required for everyday driving from the WCUs, as well as insight into the breadth of training needs and experiences which may be observed overtime by the ECs. No limits were placed on age, environment of use or experience, or condition. Individuals were included who were cognitively well, and able to speak English well enough to participate in a structured think-aloud interview. English language abilities and cognition sufficient to engage in a conversation with the researcher were screened in phone calls with the prospective participant prior to enrolling them in the study.

4.2.4 Data Collection

We collected data with each of the participants using a structured, two stage think-aloud process, combining both concurrent and retrospective think-aloud methods.[141] In the first stage (concurrent think-aloud), participants were asked to perform each of the seven indoor driving tasks described above in a PWC. To complete these tasks, WCUs used their own wheelchair, while ECs were provided with a mid -wheel drive PWC for the purposes of the study. ECs were provided with an opportunity to familiarize themselves with its use through approximately 10

minutes of unstructured driving time prior to completing the seven driving tasks. During the performance of each task, participants were instructed to verbalize the specific actions, including cognitive processes they were using to complete the being performed. They were prompted to consider the knowledge required to complete the task, and any cognitive, motor or perceptual skills and abilities they were using, using instructions such as “continue thinking aloud,” “tell me what you are noticing/seeing/considering,” and “what actions are you currently taking?”

In the second stage, following completion of all seven tasks, each participant participated in an interview (retrospective think-aloud), during which the interviewer guided them through a structured task analysis process. For each task, participants were asked to identify a set of steps required to complete the task. Participants were then asked to identify any skills, abilities, or knowledge required for task completion for each of the steps. Throughout this interview, the participant and I created a collaborative set of notes for each task which outlined the steps of the task, and required skills, abilities, and knowledge. I invited the participants to provide corrections to any assumptions made during the preparation of these notes. An example of the table used to create this set of notes is available in Appendix E.

I (EMS) conducted all interviews, as the lead investigator, and as a female occupational therapist with experience in wheelchair provision, and training and experience in qualitative research. I disclosed this information to the participants prior to the start of the study. I had no pre-existing relationship with any of the WCUs, however did have pre-existing relationships with all of the ECs involved.

4.2.5 Data Analyses

Both the concurrent (stage 1) and retrospective (stage 2) think-aloud processes were audio recorded and transcribed verbatim. Notes outlining the steps, skills, abilities, and

knowledge developed during each interview were compared with the interview transcripts from both stages to ensure no concepts were missed in the creation of the notes. Data were then separated into steps for task completion, and skills, abilities, and knowledge required. Analyses for each type of data is described below

4.2.5.1 Steps for Task Completion

Following the first WCU interview, a set of steps was developed for each task. After each subsequent WCU and EC interview, the steps were compared to the previous set of steps to create a consolidated list of steps for task completion. Data were analyzed for WCUs first, followed by ECs. Following the completion of all interviews, the final consolidated list was compared against each of the previous lists of steps to ensure applicability across all participants. Where there were disagreements or inconsistencies identified in the steps for each task, the step(s) used by the majority (i.e., 6 or more participants) was included. Disagreements or inconsistencies are reported in the results. To facilitate use of these data, process mapping was applied to each of the tasks. Process maps are visual representations of the progression of a task which outline the steps required, decision points and options for task completion.

4.2.5.2 Skills and Abilities

To develop a greater understanding of the task demands of PWC use, we were interested in knowing the skills and abilities used throughout the completion of PWC driving tasks. These skills and abilities provide information to researchers and clinicians about the areas where a client may need to develop proficiency, or develop compensatory strategies to overcome functional limitations, in order to be a successful driver. Furthermore, they may provide a basis for the development and implementation of comprehensive assessments and training programs for PWC use. We analysed the skills and abilities identified by participants using a deductive

process of directed content analysis, using the International Classification of Functioning, Disability and Health (ICF). Directed content analysis is a qualitative approach guided by preexisting theories or research when formulating codes for the data, and is considered a deductive approach to qualitative inquiry.[100] This approach is particularly useful where one is not seeking to establish novel theory based on the data.[100] We used the ICF as an existing conceptual framework for categorizing skills and abilities, as a standardized method for classifying body structures and functions, activities and participation, and environmental factors which may impact an individual's task performance.[5]

Skills and abilities identified during the think-aloud and guided task analyses across all seven tasks were combined into a single list of skills used for PWC driving. To categorize the skills and abilities required, similar terms were combined and verified by a second investigator (WBM). Once a single list of skills and abilities was established, each term was mapped to a specific code representing a body structure/function or activity/participation domain of the ICF. Terms were classified by both Chapter, Level 1, and Level 2 codes, representing nested concept areas within the ICF. Level 2 codes represent the most specific descriptor available for each term and were identified wherever possible. Where there was no specific descriptor for which the ICF definition matched the term identified in the think-aloud process, a Level 1 code was identified.

4.2.5.3 Knowledge

Although domains of the ICF exist relevant to the acquisition and use of knowledge there are no options for categorizing the types of knowledge acquired or used. Therefore, secondary analyses of the knowledge identified by the participants was conducted using a conventional content analysis approach to classify the types of knowledge required.[100] Conventional content analysis is used to describe a phenomenon where there may be little theory or existing

knowledge to guide the analysis.[100] This is an inductive form of analysis where the data drives the identified categories.[100] Knowledge 'items' identified by each of the participants were drawn from the interview transcripts and consolidated task notes created during the think-aloud process. Each of these were assigned codes according to the type of content. Codes were further refined in two subsequent rounds of coding to identify knowledge domains and specific knowledge areas. Codes were then reviewed to ensure they continued to match the knowledge domains after the three rounds of coding.

4.2.6 Trustworthiness

We crafted the methods to promote credibility through triangulation of informants with varying experience and background (PWC users and clinicians)[97] and the use of member checking.[97] To address dependability, study procedures are reported in detail.[116] As in the previous study, transferability is promoted through maximal variation sampling, but limited by the single geographical region represented by the respondents. Finally, we addressed confirmability through detailed methodological description, and the presentation of results which is representative of the data and demonstrates clear links between the data and results.[116]

4.3 Results

4.3.1 Participant Demographics

There were 10 participants including five experienced WCUs, and five ECs. Following the completion of the think-aloud process with 10 participants, there was limited new data being provided, suggesting sufficiency of the data collected, therefore no further participants were recruited.[142] All participants spoke English as a first language and used their right hand to operate the joystick. Clinicians represented a range of settings and client populations. Table 4.2

provides demographic data for the wheelchair user participants. Table 4.3 provides demographic data for expert clinician participants.

Table 4.2 Participant Demographics: Wheelchair Users

#	Age *Sex*	Diagnosis	Level of Education	Daily PWC Use (Hrs.)	PWC Use (Yrs.)	Drive Configuration
1	45-49 *F*	Paraplegia	High School	8	20+	Rear
2	55-59 *F*	Spina Bifida	High School	16	20+	Mid
3	60-64 *M*	Multiple Sclerosis	Undergraduate	18	5-9	Mid
4	55-59 *M*	Tetraplegia	Graduate	14	20+	Mid
5	55-59 *M*	Stroke	Graduate	4	15-19	Mid

Table 4.3 Participant Demographics: Expert Clinicians

	Profession	Highest Level of Education	Years Practicing	Practice Setting	Population Served
1	Physical Therapist	Graduate	20+	Pediatric Clinic	Pediatrics
2	Occupational Therapist	Undergraduate	15-19	Residential Care	Older Adults
3	Occupational Therapist	Graduate	5-9	Community	Frail Elderly
4	Occupational Therapist	Graduate	5-9	Residential Care	Older Adults
5	Assistive Technology Professional	Undergraduate	20+	Rehabilitation Centre	Adults and Older Adults

4.3.2 Steps for Task Completion

The seven PWC driving tasks were broken into steps, with each task containing between 7 and 10 steps to complete. Figures 1 through 7 represent the process maps developed for each task analyses. Six of the process maps below (Figures 4.1-4.3 and 4.5-4.7) follow established

process mapping standards: Ovals represent start/end points, rectangles represent steps in the sequence, and diamonds represent decision points. Call outs to the side represent key motor, cognitive, or perceptual considerations for each step of the task. Each task is represented at the first step with a number in a small circle; these circled numbers are used throughout all process maps to identify connectors to other tasks which may be used before, during, or after that step. Two tasks (1 and 6) include options for task completion and therefore increased complexity. Specifically, driving straight and stopping required a decision about the type of stop (sudden vs. planned) and driving through a hinged doorway differed based on the direction of swing of the door (away vs. towards the driver). One task, manipulating in a congested area (Figure 4), is represented differently from the standard process maps due to the non-linear approach to this task. It is represented as a series of considerations and actions which the wheelchair user must take when completing the task. Throughout all seven tasks, a continuous process of scanning to maintain environmental awareness was identified including considerations for people in the environment, behaviours, potential obstacles, thresholds, and changes in flooring.

There were key differences noted in task completion between participants specifically for Task #5 (navigating an elevator). While most participants chose to drive forward into the elevator and then complete a 180-degree turn, two participants (one WCU and one EC) preferred to back into the elevator to avoid turning within the tight space. One participant (WCU) also preferred to position themselves in the corner of the elevator to address potential personal vulnerabilities associated with other users of the elevator being positioned behind them.

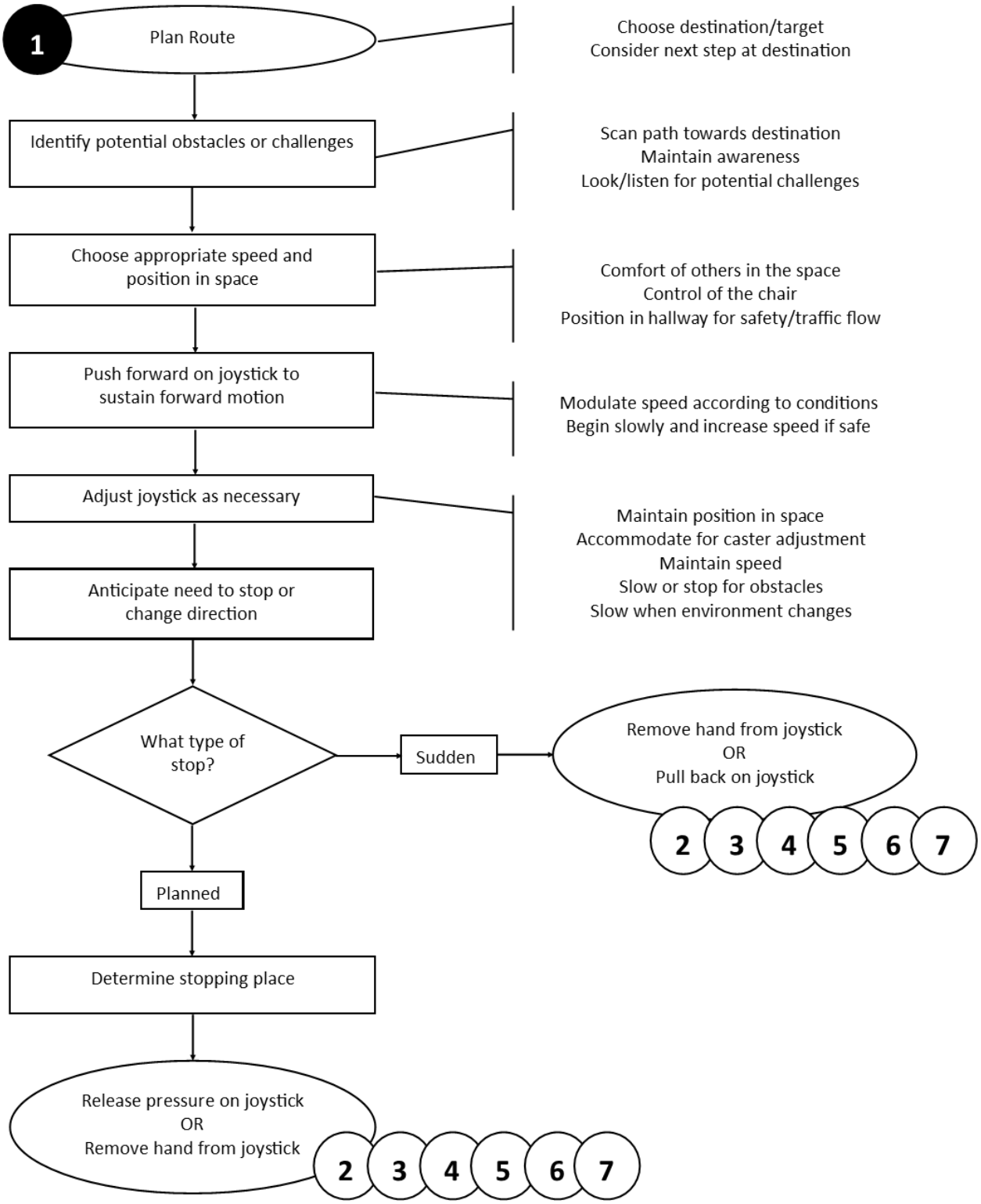


Figure 4.1 Task #1 - Driving Straight and Stopping

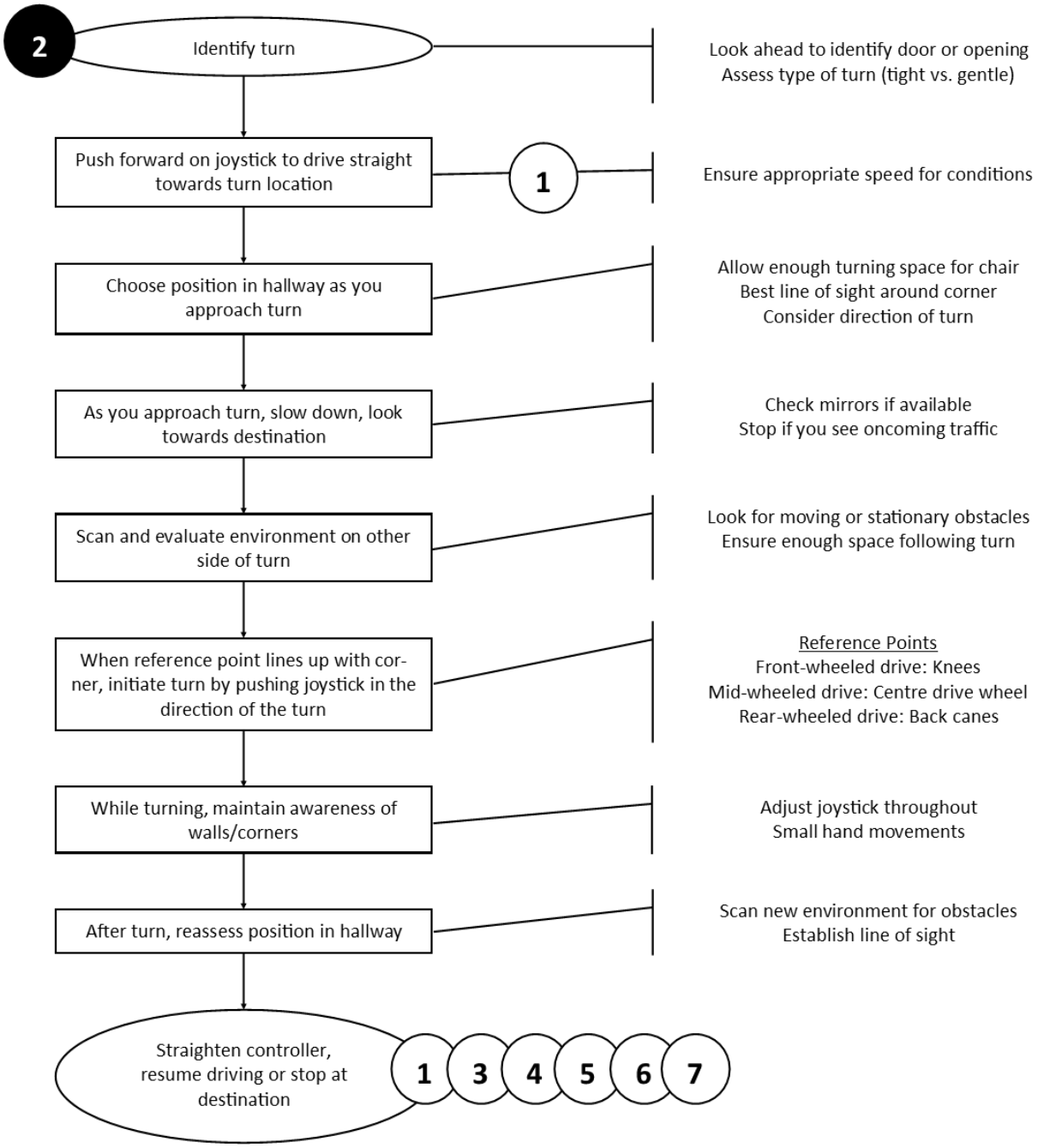


Figure 4.2 Task #2 - Turning 90 Degrees While Moving Forward

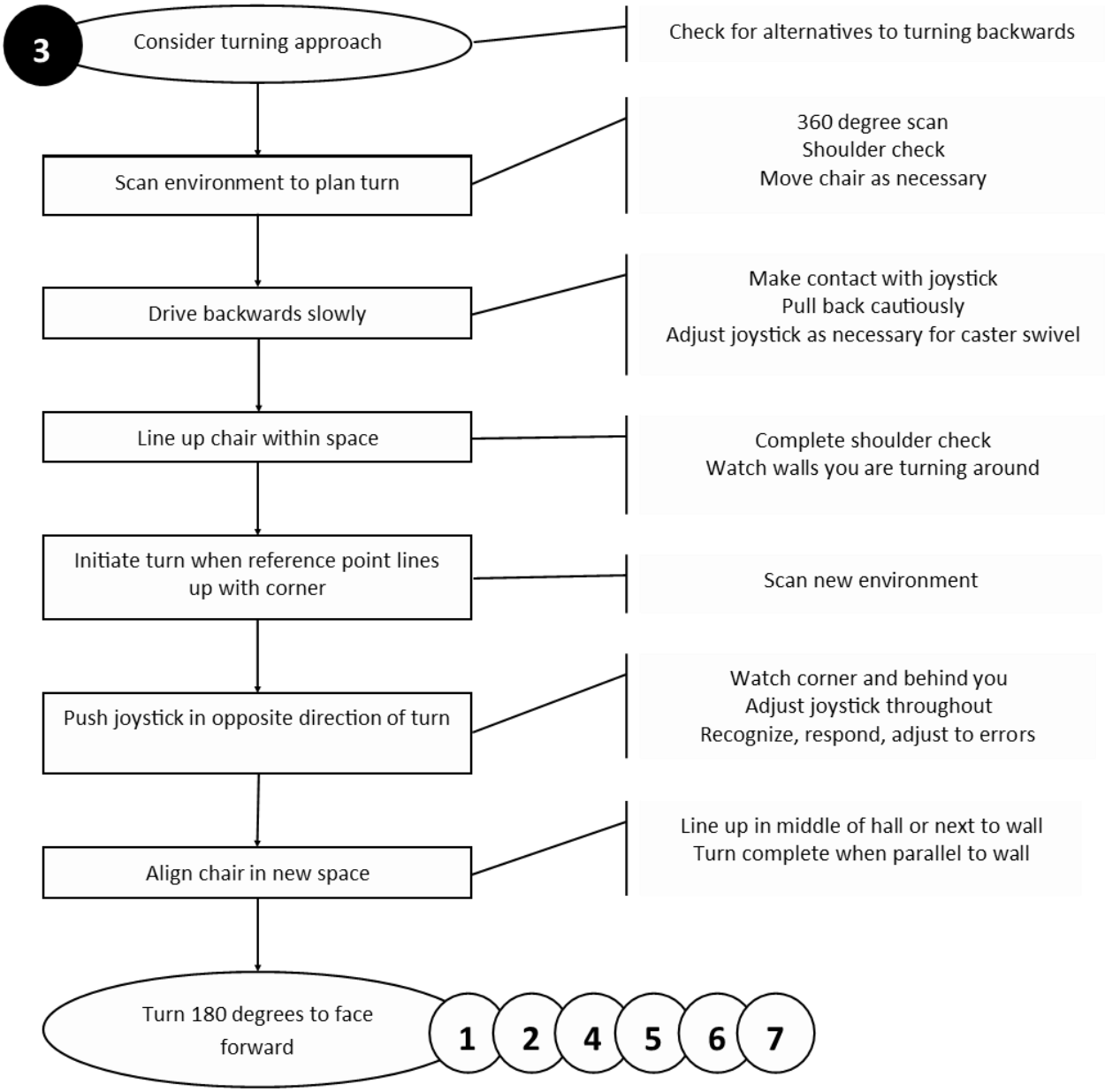


Figure 4.3 Task #3 - Turning 90 Degrees While Moving Backwards

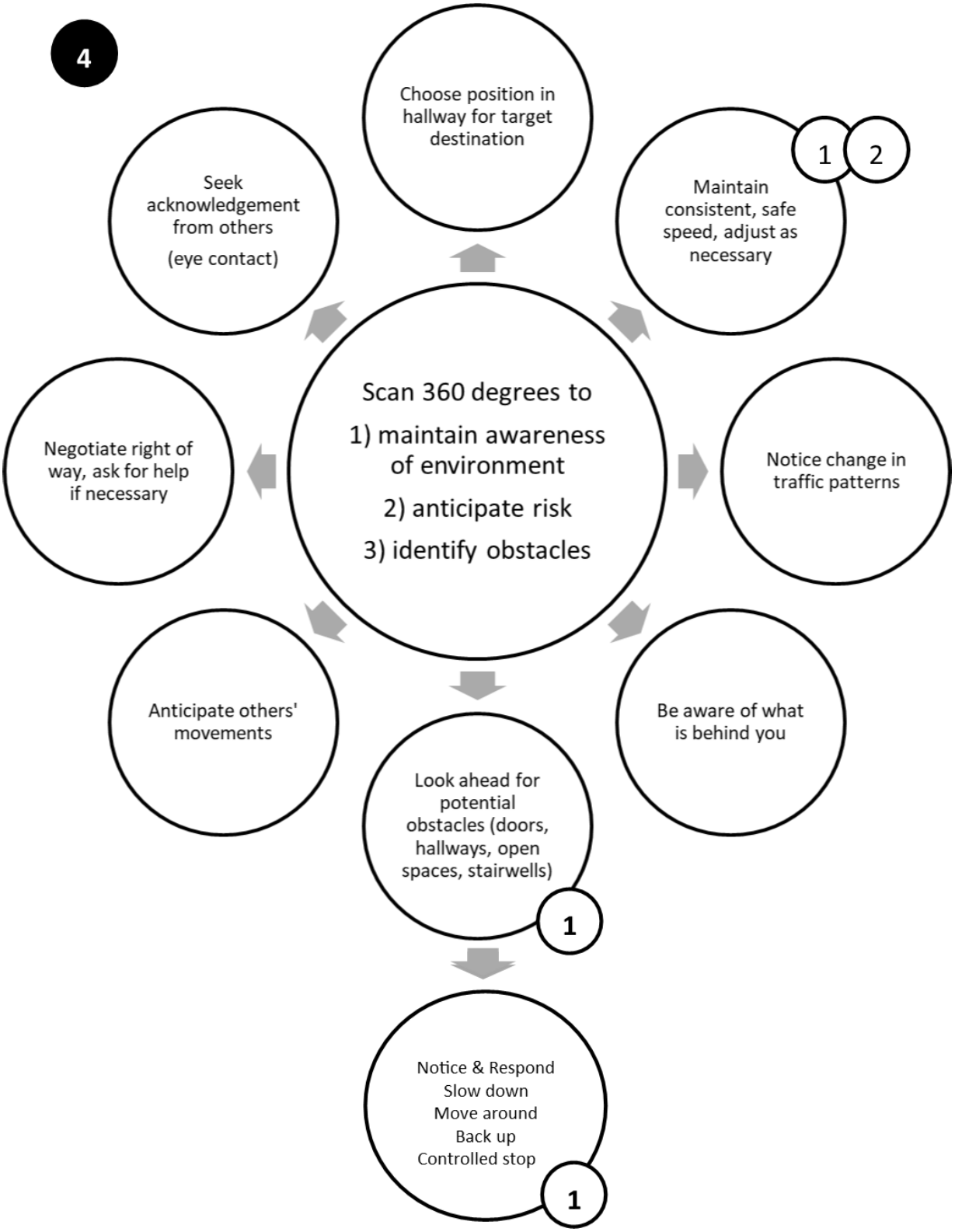


Figure 4.4 Task #4 - Manipulating in a Congested Area

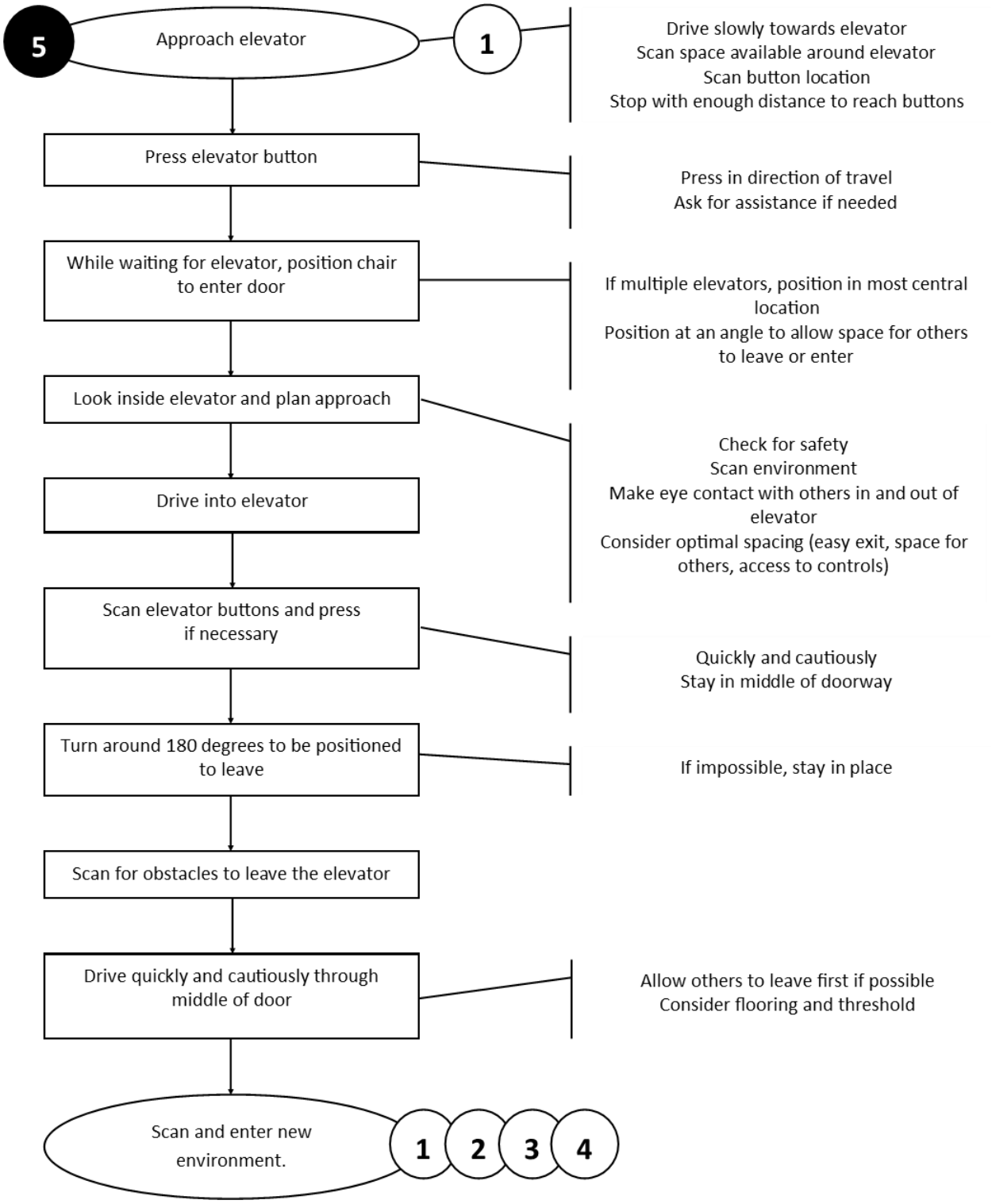


Figure 4.5 Task #5 - Navigating an Elevator

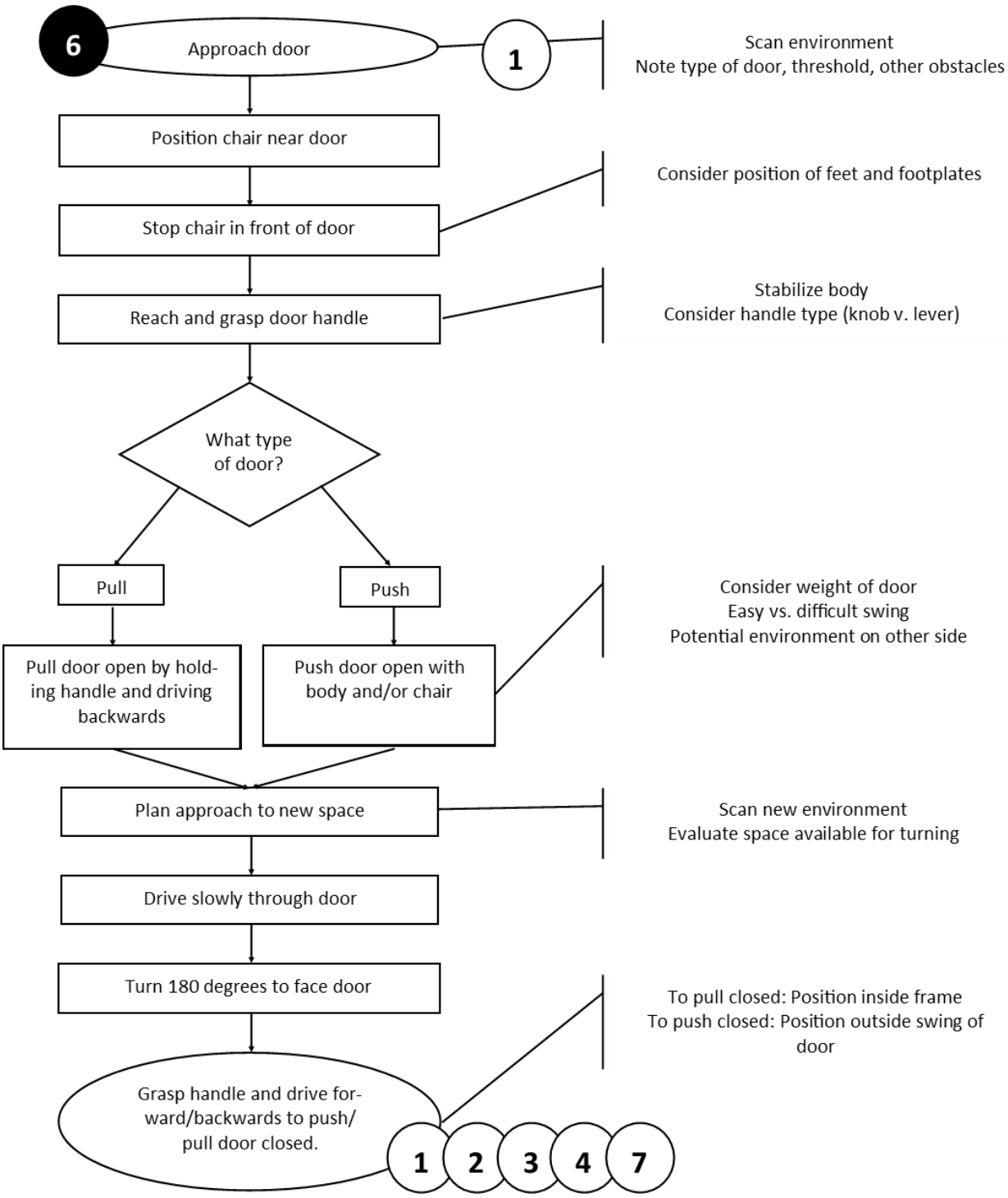


Figure 4.6 Task #6 - Driving Through a Hinged Door

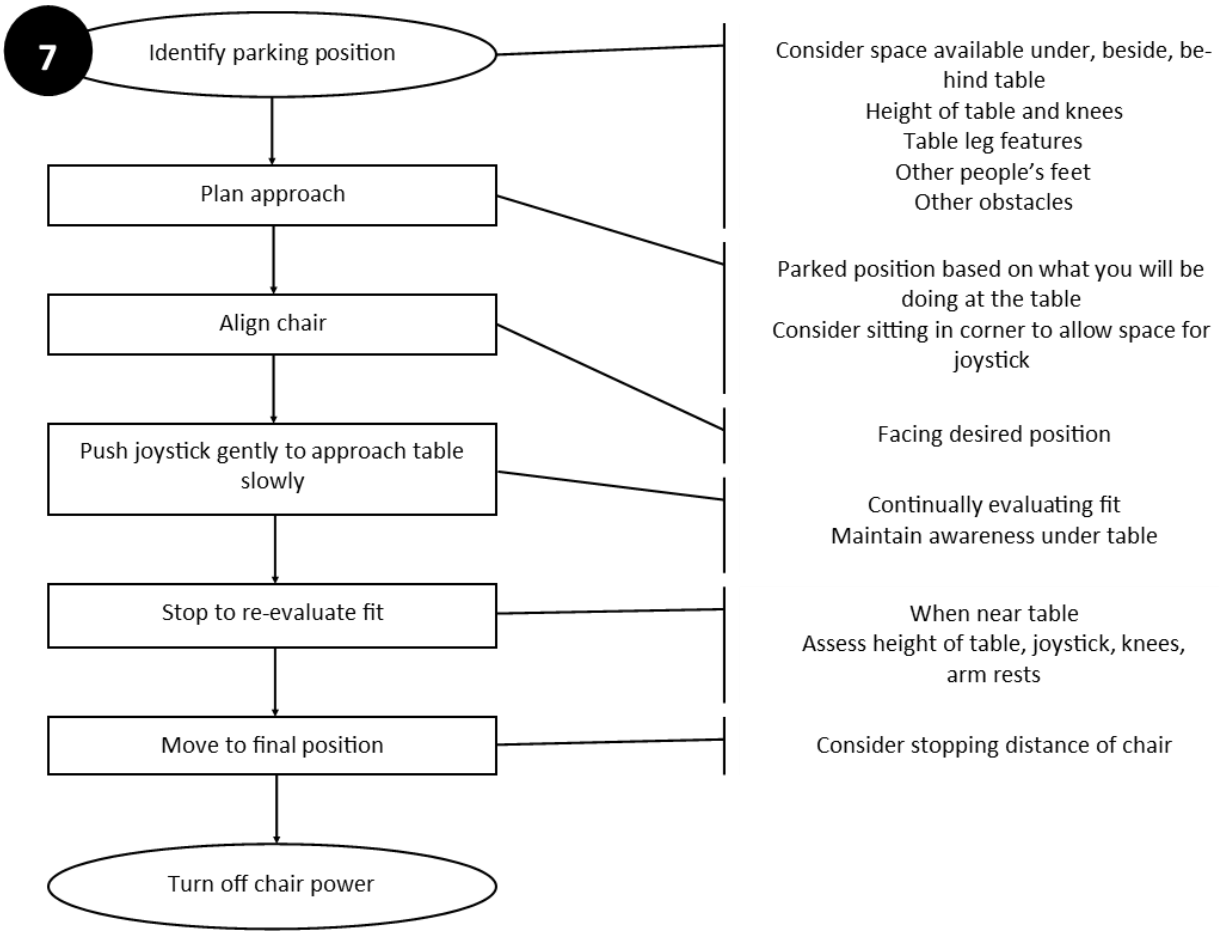


Figure 4.7 Task #7 - Parking at a Table

4.3.3 Skills Required for Powered Wheelchair Driving

Throughout the interviews, 110 distinct skills and abilities were identified which are used when completing PWC driving tasks. Each of these skills was mapped to an ICF code. Eighty skills were mapped to codes in the Body Structures and Functions domain (i.e., mental functions, physical functions, sensory and pain functions), and 30 skills were mapped to codes in the Activities and Participation domain (e.g., learning and applying knowledge, interpersonal relationships). Mental functions represent approximately 50% of the identified skills. ICF codes and domains, mapped to individual identified skills can be seen in Tables 4.4 (Body Structures & Functions) and 4.5 (Activities & Participation).

Table 4.4 Skills and Abilities Used in PWC Driving: Body Structures and Functions Domain

Chapter	Level 1 Code	Level 2 Code	Identified Skills
b1. Mental Functions	b110 Consciousness functions		Alertness
	b114 Orientation functions		Orientation
		b1141 Orientation to place	Orientation to space
	b122 Global psychosocial functions		Empathy, patience
	b126 Temperament and personality functions		Attitude
		b1266 Confidence	Confidence, assertiveness
	b140 Attention		Attention, awareness of the environment, awareness of others, concentration
		b1402 Dividing attention	Divided attention
	b144 Memory		Memory
		b1442 Retrieval of memory	Previous experiences
	b152 Emotional functions	b1521 Regulation of emotion	Emotional regulation, breathing
		b1528 Emotional functions, other specified	Humour
	b156 Perceptual functions	b1561 Visual perception	Noticing, scanning, peripheral vision
		b1564 Tactile perception	Tactile
		b1565 Visuospatial perception	Depth perception, alignment, location in space, spatial awareness, visuospatial
	b164 Higher-level cognitive functions		Information processing, cause and effect, cognition, cognitive processing, calculation, estimation, evaluation
		b1641 Organization and planning	Path planning, anticipating task requirements, awareness of upcoming needs, planning, prioritization
		b1642 Time management	Timing

Chapter	Level 1 Code	Level 2 Code	Identified Skills
b1. Mental Functions	B164 Higher level cognitive functions	b1643 Cognitive flexibility	Adapting, accommodating changes, adjusting behaviour, adjusting driving to suit changes in the environment
		b1644 Insight	Awareness of own body, insight
		b1645 Judgement	Judgement
		b1648 Higher-level cognitive functions, other specified	Understanding consequence of error, assessing and anticipating risk
	b176 Sequencing complex movements		Sequencing
	b180 Experience of self and time functions	b1800 Experience of self	Position in space, position of chair
		b1802 Experience of time	Awareness of time
b2. Sensory and Pain Functions			Sensory, sensation, sensitivity
	b210 Seeing functions		Gaze, vision, visual processing
	b230 Hearing functions		Auditory cues, hearing
	b234 Vestibular functions		Sitting balance, vestibular
	b260 Proprioceptive function		Position of wrist, positioning of body, proprioception
b7. Neuromusculoskeletal and Movement-Related Functions	b710 Mobility of joint functions		Range of motion in neck
	b730 Muscle power functions		Strength
		b7300 Power of isolated muscles and muscle groups	Calibration of force
	b755 Involuntary movement reaction functions		Postural stability, reaction time
	b760 Control of voluntary movement functions		Adjust, bilateral skills, motor control, move wheelchair, sustain movement, wrist extension, speed control, stopping
		b7602 Coordination of voluntary movements	Coordination

Table 4.5 Skills and Abilities Used in PWC Driving: Activities and Participation Domain

Chapter	Level 1 Code	Level 2 Code	Identified Skills
d1. Learning and applying knowledge	d110 Watching		Observation
	d115 Listening		Listening
	d160 Focusing attention		Focus
	d175 Solving problems		Assess environment, assessing safety, compensate, identify errors, synthesize knowledge, problem solving
		d1751 Solving complex problems	Anticipate behaviour of others, anticipate change to driving to accomplish task, anticipate obstacles, situation management
	d177 Making decisions		Adjust speed of chair, choose joystick hand, choosing, choose speed, projection
d3. Communication	d315 Communicating with – receiving – nonverbal messages	d3150 Communicating with – receiving – body gestures	Understanding body language
d4. Mobility	d410 Changing basic body position	d4105 Bending	Bending
	d440 Fine hand use	d4401 Grasping	Grasp
		d4403 Releasing	Release
	d445 Hand and arm use	d4452 Reaching	Functional reach
d7. Interpersonal interactions and relationships	d710 Basic interpersonal interactions	d7108 Basic interpersonal interactions, other specified	Seeking assistance
	d720 Complex interpersonal relationships		Alerting others
		d7203 Interacting according to social rules	Eye contact, driving etiquette, rules of the road, courtesy
		d7204 Maintaining social space	Social skills
		d7208 Complex interpersonal relationships, other specified	Advocating for oneself

4.3.4 Knowledge Domains

Four knowledge domains were identified which represent areas of knowledge used during PWC driving. The four domains identified include knowledge of self, knowledge of the environment, knowledge of the wheelchair, and knowledge of the activity or task. Table 4.6 provides a hierarchical representation of knowledge domains with specific knowledge used. Knowledge of self represents the information a wheelchair user may need to have about their own abilities, limitations, and emotional regulation which influences their capacity to complete specific tasks. Knowledge of the environment includes knowledge about the physical, social, and institutional environment, and those factors which may influence their ability to navigate a route or operate the wheelchair safely. In the social environment, participants described the importance of understanding the potential behaviours of others who they might encounter while driving as being important to their capacity to navigate in their wheelchair. Knowledge of the wheelchair includes knowledge of the capabilities of the chair (e.g., ability to navigate obstacles, thresholds and curbs), operations (e.g., how to operate the wheelchair functions), size, and programming parameters. Knowledge of the activity or task included knowledge of the task goal, including specific task requirements (e.g., intended activity to be performed once parked at a table and positioning requirements), steps to execute the task or activity, and consequences of potential errors or inability to complete the task.

Table 4.6 Knowledge Domains and Specific Knowledge Areas for PWC Use

Knowledge Domain	Specific Knowledge Areas		
Self	Abilities and limitations		
	Emotional regulation		
Environment	Social	Expected behaviours	
		Role of companion	
		Communications	
		Behavioural norms/Etiquette	
	Physical	Characteristics	
		Geography	
		Risks and obstacles	
	Institutional	Rules of the road	
Wheelchair	Capabilities		
	Casters		
	Operations	Wheelchair controls	
		Joystick	
		Speed	Proportionality
		Drive configuration	
	Size	Footprint	Width
			Turning radius
		Height	
	Programming	Speed	
		Acceleration	
		Deceleration	
		Turning	
		Joystick	
Activity or Task	Goal	Requirements	
	Execution	Path planning	
	Consequences	Potential errors	

4.4 Discussion

In this study, we aimed to determine the common steps used to achieve completion of each of seven indoor driving tasks, and associated skills, abilities and knowledge for PWC driving. This study is the first systematic approach to assessing the task demands for PWC use using a task analysis approach. It provides insight into the detailed processes which are used to

complete basic to advanced PWC driving tasks, which can be used for the development and implementation of PWC skills training programs (especially forward and backward chaining approaches) and PWC skills assessments.

While the results indicate common experiences for most of our participants, it is worth considering whether the steps identified necessarily represent the 'correct' way to compete the task, or simply the method used most commonly. It is possible there are more efficient or safe methods for task completion which are not commonly used; these were not explored in the present study. Alternative approaches may be apparent in the differences found, especially in the elevator navigation task. It is possible the two participants who elected to back into the elevator to avoid turning are completing this task in a more advanced or efficient manner, however this also renders the task more complex. Backing into the elevator requires greater awareness of the environment around the wheelchair, including potential obstacles or people who may be more difficult to see when backing than when driving forwards. As a result, completing the task in this way may be less suitable for a novice wheelchair user who is undergoing initial training.

We were able to identify a wide range of skills, abilities, and knowledge which were used throughout task completion. It was interesting to note throughout the interviews that there was substantial repetition of each of the skills, abilities, and knowledge across all tasks, implying that none of the skills, abilities, or knowledge domains were unique to a particular task. This underscores the complexity of PWC driving, where the driver must integrate sensory input, motor output, cognition and problem solving, and the management of knowledge throughout the driving process.

While we identified the skills, abilities and knowledge most commonly used by the participants, there is no evidence from this study to suggest that any are critical skills required

for safe or effective driving. Although we are unable to speak to whether these skills and abilities are required for safe and effective driving, they represent the first empirical analyses of the tasks of PWC driving. The analyses provide a framework for future research to investigate which of these skills, abilities, and knowledge are critical, and which may be overcome using compensatory strategies to allow an individual to be an independent driver. There is evidence to suggest that some of the skills identified (e.g., problem solving, visual perception) are associated with frequency of wheelchair use, however no evidence has been published demonstrating the requirements for these abilities in order to achieve success as a driver.[47,48] In fact, there is evidence which suggests individuals who lack in some of these areas including those with severe neglect, or those with impaired vision, are able to learn the requisite skills to be safe and competent drivers.[33,143,144] Therefore, these should not be used as the basis to exclude an individual from PWC use.

The ICF was used to categorize the skills and abilities identified by our participants including those body structures and functions, and activity and participation domains which may be relevant when training a new PWC user. There were also overlapping areas between the skills and abilities, and the knowledge required, notably the integration of skills, abilities, and knowledge. This skill is identified by the ICF as the ability to use the knowledge the individual already has. Furthermore, there are additional grey areas, including the function of insight, which may have substantial overlap with knowledge of the self, or social skills, which overlap with knowledge of the social environment. This is due, primarily to the development of the ICF to aid in diagnostic categorizations of functioning. The ICF does capture various environmental considerations which may impact a wheelchair user throughout the experience of driving, and provides an opportunity to explore the environmental factors which may act as facilitators or

barriers to performance.[145] However, the ICF was not able to capture the depth of information required to assess the knowledge used by drivers on a regular basis. For this reason, we completed a secondary qualitative analysis of the knowledge domains.

The knowledge domains and specific knowledge areas identified included knowledge of the self, environment, wheelchair, and activity or task. These knowledge domains correspond well to an existing theory of assistive technology provision known as the Human Activity Assistive Technology (HAAT) model.[146] The HAAT model provides a framework from which to understand performance with assistive technologies, through examination of the human, activity, and assistive technology, located within a particular context.[146] In this case, our results correspond well, with knowledge of the self representing the human component, knowledge of the activity or task representing the activity, knowledge of the wheelchair representing the assistive technology, and knowledge of the environment representing context. This supports the use of the HAAT model in developing assistive technology interventions, particularly where there may be knowledge domains which should be integrated into a training program.

4.4.1 Limitations

This study focused solely on indoor driving tasks and the commonly used steps, skills, abilities, and knowledge used to complete those tasks. While we expect these to transfer to similar outdoor tasks, the increased complexity of the outdoor environment should not be underestimated. Therefore, further research is required to assess differences in task demands for outdoor PWC use. This study is also limited by the drive configuration of the wheelchairs used by both the WCUs and ECs. All participants except one completed the study using a mid-wheel drive PWC, which impacts how tasks are completed. It is possible there are differences for other drive configurations which are not captured in the results. However, as the majority of

individuals living in residential care use mid-wheel drive PWCs, the results are likely transferable to this population. Furthermore, we were unable to assess the relative importance of each of the identified skills and abilities, or whether each of the skills, abilities, and knowledge domains are requirements for competent wheelchair use. Further study is required to assess the relative importance of each of the skills. Additional research may help to determine if individuals can become competent drivers if any of the identified skills, abilities, or knowledge domains are areas of limitation for them individually.

The use of the ICF as a framework for a directed content analysis approach constrains the results to those categories available in this specific framework. However, this improves transferability of the results to clinical settings, and provides a structure for future research in the area. It is possible there would have been different or additional insights with an inductive approach to analysis of the skills and abilities.

There is additional research to be completed to address transferability of the work to other populations. For example, certain populations (e.g., individuals with hemiplegia) may experience greater challenges with some tasks, which would necessitate additional skills or abilities to overcome these challenges. It may also be useful to consider this approach with individuals who are limited in one or more of the functional areas (e.g., visual functions) to gain a better understanding of the strategies used to compensate for these limitations.

Finally, we attempted to use similar environments for all participants. However, the presence of static or dynamic obstacles in each task may have increased or decreased its relative complexity. It is possible there may be task considerations which are not included in this study as it was not possible to understand task demands in all possible environments an individual could encounter.

4.5 Conclusion

PWC use is complex and requires a variety of skills and abilities from all areas of human functioning, including complex activity and participation domains. Training programs should address all areas of skill development or accommodate for limitations individuals may experience. The knowledge used while driving a PWC is broad and should be considered when developing PWC training programs.

Bridging Statement

In the previous three chapters, we have developed an understanding of clinical practice in PWC training, and the potential for novel programs to address gaps in these processes, discussed the potential for the use of shared control to enhance PWC skills training, and explored the task demands of PWC driving, including steps required to complete indoor driving tasks. In Chapter 5, we have described and evaluated the feasibility of implementing a PWC skill training program which combines these components to address the gaps in PWC training for older adults with cognitive impairments.

The feasibility study protocol described in Chapter 5 has been accepted for publication in the Canadian Journal of Occupational Therapy.

Chapter 5: Evaluation of the Feasibility of an Errorless Approach to Powered Wheelchair Skills Training using Shared Control

As I highlighted in Chapter 4, the exploration of the task demands of powered wheelchair (PWC) driving, opportunities for success in PWC use are dependent on an individual's skills and abilities, including cognitive and perceptual abilities, diagnosis and prognosis, and environments of use.[36,37] As a result, despite the potential benefits of PWC use, many individuals who would benefit do not get access, particularly if they are unable to demonstrate the required skills: capacity to safely negotiate the environment, avoid obstacles (including people), and recognize when assistance is needed.[40]

PWC skill training can be provided to address some of the challenges new users may face, and to mitigate the potential risk to the user or others in their environment.[33,34] In a study investigating residential care PWC guidelines, a majority of respondents felt more in-depth training was required, particularly when there are limitations to cognition, movement, or vision.[27] This training ideally considers both the capacities of the learner, and the characteristics of the environment of use.[37–39] However, as discussed in Chapter 2, limitations including a lack of effective training protocols, available clinical time for training, and concerns about safety in the training process often result in inadequate training provided to the individuals who need more in-depth or tailored learning opportunities.

Specifically, individuals with cognitive impairments are often denied access to training, or given training which does not meet their learning needs, limiting their ability to obtain or maintain use of a PWC.[37] Clinicians may be hesitant to engage in PWC training, particularly with learners with cognitive impairments, citing concerns they will not be able to effectively

respond to safety issues in the training process. Furthermore, meeting the specific learning needs of cognitively impaired learners is necessary for success. For those with intact cognition, trial-and-error learning can be used, as short-term, working memory allows for recall of the error, and correction in subsequent trials. With age-related cognitive decline, short term and working memories associated with learning are typically affected.[53] Difficulty with verbal recall is hypothesized to be associated with challenges remembering operational instructions for the device and the actions which led to errors in a previous trial.[48]

CLT suggests that for learning to occur, intrinsic load (inherent difficulty of the task itself) and extrinsic load (difficulty of the learning environment and training approach) types of load must be balance with germane load (cognitive load associated with the task of learning).[66] Reducing intrinsic load can be done through modification of the task to reduce complexity, while reducing extrinsic load may be done by modifying the environment of training or the training approaches. For individuals with cognitive impairment, errorless training approaches may help to balance extrinsic load, particularly by modifying the training to reduce reliance on explicit memory processes for recalling errors,[54,55] Errorless training techniques, including modelling and demonstration, cued learning without and with fading, and spaced retrieval, rely on implicit memory processes which remain relatively intact in the presence of memory loss and other cognitive decline.[56,57] While largely used in the literature for the development and rehabilitation of recall based memory and language tasks,[147] these techniques have shown promise in teaching (or re-teaching) procedural skills to individuals with cognitive impairment, including development of morning routines for chronic diabetes management,[148] activities of daily living and instrumental activities of daily living,[149] and prosthetic limb fitting.[150] Applying errorless learning to PWC skills training is a novel approach which has previously not been documented

in the literature. To apply these training strategies, clinicians require increased control over the wheelchair to tailor the task to the learner and prevent sources of error. Teleoperation, or shared control can provide a trainer with the opportunity to override the wheelchair user's controls, much like a second steering wheel and brake in a driver-training car. Chapter 3 described the clinical utility of shared control for PWC skills assessment and training and identified the potential use of the technology for increasing the control provided to the trainer, which would allow alternative approaches to training, similar to those described in the errorless learning literature (e.g., modeling, forward chaining).[151] Furthermore, clinicians identified the potential for reduced risk in the training environment, which has previously been identified as a training related barrier.[151] Finally, the reduced risk may allow the trainer to increase the amount of training completed in natural environments, which may be more effective for learning for individuals with cognitive impairments and may help to decrease the time required for training.[151]

This chapter reports on feasibility of the Collaborative power Mobility Innovative Learning OpporTunity (CoPILOT) approach, an errorless learning program for PWC skills training, facilitated by shared control technology.

5.1 Objectives

The overall objective of this research is to develop and evaluate the feasibility of a randomized controlled trial protocol investigating an errorless approach to PWC training used in residential care for older adults with cognitive impairment. There are four specific objectives:[79]

1) To evaluate the feasibility of study *processes* including participant recruitment, consent, retention, and treatment adherence.

2) To evaluate the feasibility of study *resources*, including the time required to complete data collection, and trainer time required to deliver the intervention; and

3) To evaluate the feasibility of study *management*, including equipment reliability, participant processing time, and protocol administration; and

4) To evaluate the feasibility of *treatment* implementation, including safety, intervention and dose response, and treatment effect.

Table 5.1 provides criteria for success set a priori for each of the feasibility objectives. These criteria were based: 1) Previously published literature in the area (e.g., expected rate of recruitment), 2) Pragmatic considerations (e.g., funding constraints on staff time), and 3) Criteria determined by the team to meet a level of acceptability in clinical practice, understanding the limitations of research with prototype technologies (e.g., number of sessions with technological issues). While treatment effect is assessed, we are aiming to develop a better understanding of which outcomes should be considered most important, and to have an estimate of the effect size to inform sample size calculation for a definitive randomized controlled trial (RCT).

5.2 Methods

5.2.1 Trial Design

A 2x2 factorial, mixed-methods, evaluator masked feasibility RCT was used to evaluate the feasibility of study methods for use in a definitive RCT, and to compare the effect of the CoPILOT intervention on wheelchair skills, wheelchair related confidence, wheelchair related goal satisfaction, capacity for divided attention while driving, and health related quality of life, as compared to a control intervention (Wheelchair Skills Program; WSP). The two factors investigated were type of training (CoPILOT vs. WSP control) and training time (6 sessions vs. 12 sessions), including their effects on the primary and secondary clinical outcomes, and

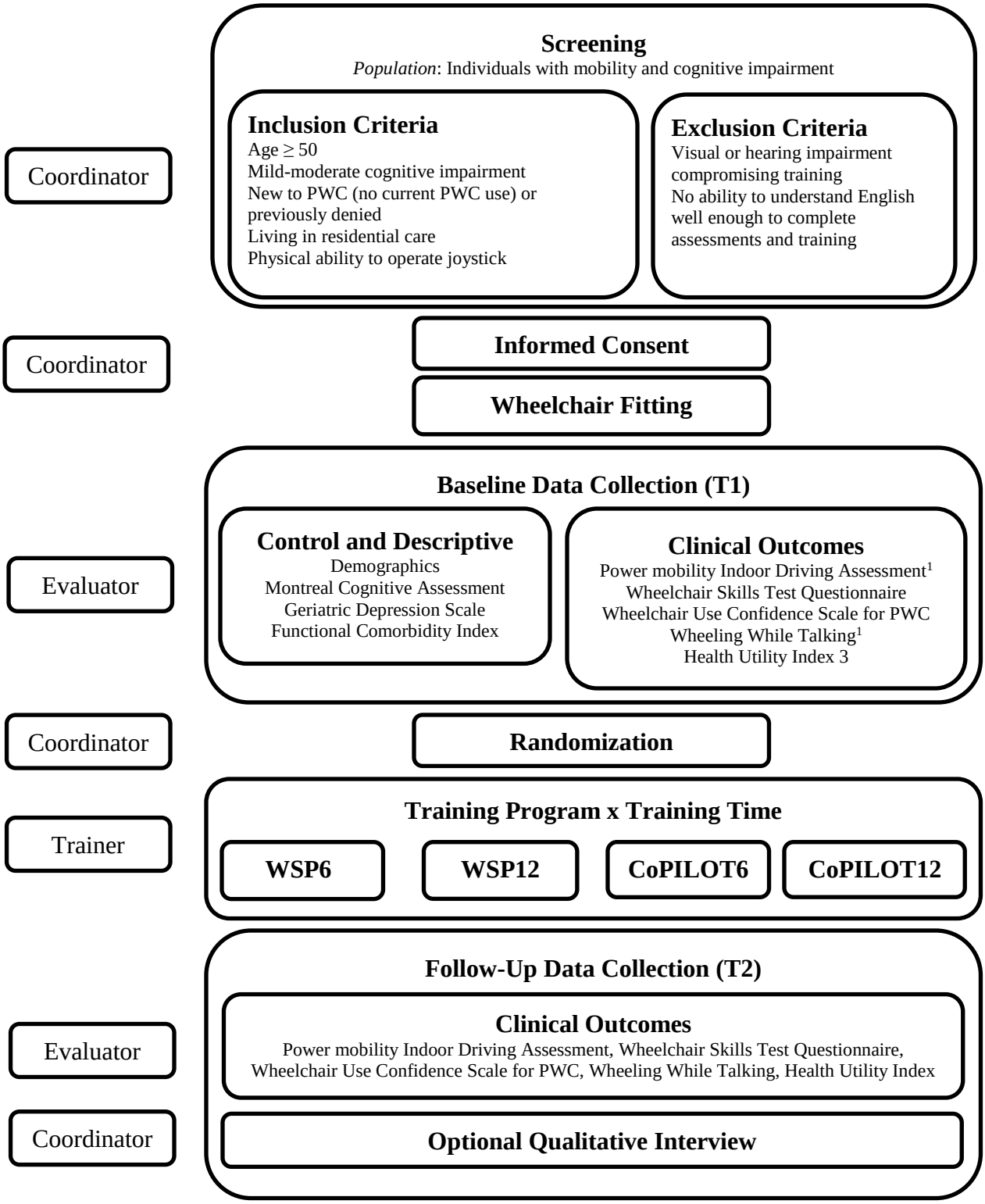
potential interactions between factors. Combination of the two factors resulted in a total of four groups: CoPILOT6 (CoPILOT intervention; 6 sessions), CoPILOT12 (CoPILOT intervention; 12 sessions), WSP6 (control intervention; 6 sessions), and WSP12 (control intervention; 6 sessions). A visual representation of the trial design and flow is provided in Figure 5.1 and a CONSORT diagram is provided in Figure 5.2.[99] Mixed methodology was used to benefit from both quantitative and qualitative approaches in addressing the feasibility objectives. Mixed methods are particularly suitable for evaluative research, where there is benefit from both quantitative measurement, and qualitative understanding.[75] We reported both quantitative and qualitative findings where each is best suited to the specific objective, allowing us to evaluate the potential for the intervention's use in future research, as well as its use in clinical practice. We have used the TIDIER guidelines for reporting intervention design and replicability,[152] and CONSORT guidelines for reporting methods and results from the clinical trial.[153]

5.2.2 Participants

We included participants if they lived in residential care, were ≥50 years old, would benefit from the use of a PWC, could operate a standard PWC joystick, and scored between 18 and 26 on the Mini Mental State Exam (consistent with mild to moderate cognitive impairment).[154] Participants were new to PWC use or previously denied due to safety concerns (e.g., previous collisions with walls). We excluded participants if their residential care occupational therapist had identified visual and/or hearing concerns that may compromise training safety, or if they were unable to speak English well enough to complete study outcome measures. English language ability was assessed conversationally by the study coordinator.

Recruitment relied on relationships our study team had cultivated with occupational therapists working in residential care in six facilities managed by two health authorities,

Vancouver Coastal Health Authority (VCH) and Providence Health Care (PHC). Occupational therapists in each facility were provided with information about the study and eligibility criteria and asked to identify potential individuals who would be eligible for participation.



[1]Only completed at baseline if participant had previous powered wheelchair experience. WSP: Wheelchair Skills Program (Control), CoPILOT: Collaborative Powered mobility Innovative Learning Opportunity (Intervention)

Figure 5.1 CoPILOT Trial Flow Chart

As the primary objective of this study was to assess the feasibility of study procedures it was not appropriate to determine sample size based on calculations from the primary clinical outcome.[156,157] We initially proposed a sample size of 32 to ensure sufficient numbers to address feasibility outcomes and ensure precision of estimated means and variance for treatment related outcomes.[155] Considering a conservative expected withdrawal rate of 25% (withdrawal of eight participants), this number was selected to ensure a group size of 12 per group by factor (24 total) for analyses.[155] The trial was stopped once we reached a total of 24 completed participants (12 per group by factor).

5.2.3 Interventions

5.2.3.1 CoPILOT

The CoPILOT intervention was a PWC skills training approach emphasizing errorless, experiential learning facilitated by shared control technology used by the trainer.

5.2.3.1.1 Development and Delivery of the CoPILOT Intervention

We developed the CoPILOT intervention according to Rogers' systems approach to intervention development, described in Chapter 1.[72] Specifically, tasks were selected from the literature, particularly existing PWC skills assessment, which were relevant to the older adult residential care population. Errorless learning approaches are applied to each of the tasks according to the Komatsu Two-Factor model (described in Chapter 1) which balances error and effort on a biaxial continuum, increasing each over time as the individual gains competence.[68] Figure 5.2 shows progression of errorless learning approaches according to this continuum. Each of the approaches included in the figure were identified in the errorless learning literature and integrated into the training program.

For each skill, performance criteria, steps for completion, potential cues, and training considerations were established based on the results of the think-aloud tasks analysis described in Chapter 4. Finally, the use of the CoPILOT remote was integrated into each skill to instruct the trainers on situations where its use would promote or enhance the errorless learning experience. The full CoPILOT Training Manual is provided in Appendix F.

The intervention was administered in familiar environments in the participant's residential care facility. During training, participants independently operated the PWC with the trainer offering verbal and visual cues, and guidance through the shared control technology to prevent a collision or unsafe event, demonstrate a skill, or promote experiential learning. For example, if a participant was learning to maneuver the chair through a hallway, and was at risk of hitting the sidewall, the trainer had the capacity to gently guide the chair away from the wall, demonstrating proper driving techniques, and preventing a collision. Trainers also had the capacity to modify speed, acceleration and deceleration rates, and turning direction as necessary, or engage the emergency stop function to prevent an unsafe event.

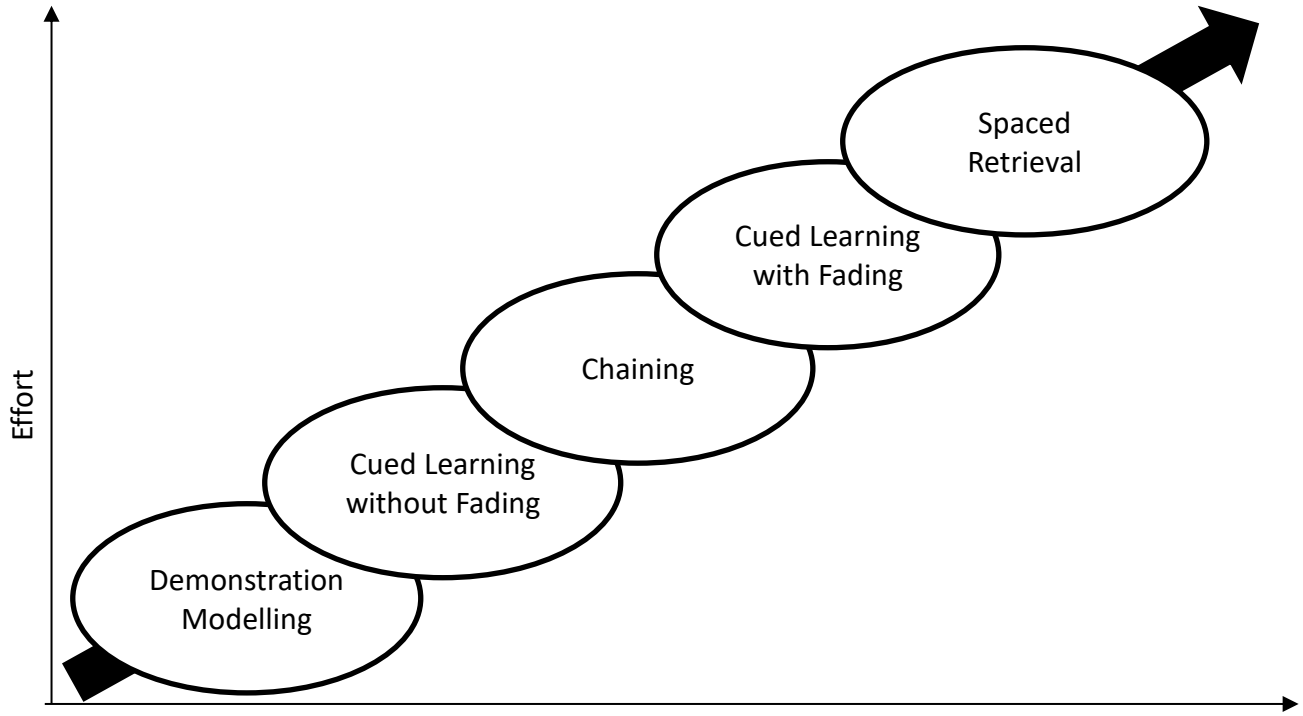


Figure 5.2 Skill Progression Incorporating Errorless Approaches

5.2.3.2 Wheelchair Skills Program (Control)

The control protocol used the Wheelchair Skills Program (WSP version 4).[101] The WSP is also the only published training protocol which has been used in clinical trials with a similar population.[33,42] Trainers provided instructions on PWC skills through verbal or visual instruction, based on motor learning principles, and were instructed to progress through 30 discrete PWC skills from basic to advanced, building on success of previously learned skills. Participants were required to consistently demonstrate safe operation of the device in a quiet environment with non-human obstacles prior to proceeding to complex environments with people present. Training was completed in a wheelchair comparable to that used in the CoPILOT protocol, but without the shared control capacity. This minimized potential differences in the training program not attributable to the CoPILOT approach. In circumstances where a trainer felt the participant was

at risk to themselves or others, they were instructed to ask the participant to stop verbally. If the situation was more urgent, they were instructed to remove the participant's hand from the joystick or turn off the chair.

5.2.4 Total Training Time

In this study, we assessed both the intervention and control protocols at two levels of training time (6 vs. 12 sessions) to determine if there was an additional effect of time, and to determine feasibility differences between these intervals. As there is no standard dose of training provided in clinical practice, and no published evidence regarding an effective dose of training, these times are consistent with published data regarding training protocols in two Canadian facilities, which found evidence of wheelchair skill acquisition at both six and twelve sessions.[41] Participants completing six sessions completed 3 sessions/week over two weeks; participants completing 12 sessions completed 4 sessions/week over three weeks. Sessions were scheduled to last a maximum of one hour, dependent upon the training tolerance of the participant.

5.2.5 Intervention Fidelity

Fidelity of the intervention was addressed across three core components of fidelity: design, training, and monitoring.[158] To address design and training, all trainers were provided with a training manual (CoPILOT: Appendix F; WSP: Appendix G) which outlined the protocol in detail and provided suggested training progressions and information about training techniques. Trainers were then provided with approximately 2 hours of 1:1 review and discussion of the protocols, including a review of the theoretical underpinnings of each protocol. All trainers were given the opportunity to practice skills required for the delivery of the intervention with a mock learner. For CoPILOT trainers (n=4), additional hands on instruction was provided on technical skills for use of the CoPILOT shared control system. The CoPILOT Technical Manual is

available in Appendix H. CoPILOT trainers shadowed also a minimum of two training sessions with an experienced CoPILOT trainer. For control trainers (n=3) who were familiar with the WSP, no further training was provided. Due to the similarity with clinical practice, control trainers did not complete any shadow training sessions.

Throughout the study, fidelity of the intervention delivery was monitored through regular audit of staff logs, where trainers reported skills and techniques used in the training process, and challenges adhering to the protocol, and through regular team meetings with the investigators and study coordinator. Trainers exclusively delivered either the CoPILOT or the control interventions to ensure there was no contamination between protocols.

5.2.6 Equipment

The PWC used for both the CoPILOT and control interventions was a standard mid-wheel drive PWC, most often used in residential care environments[159], adjusted to the participant's size, and featuring powered tilt and seating components (back rests and cushions) selected in consultation with their facility occupational therapist to promote stability and positioning for posture or pressure management.[160,161] PWCs outfitted with shared control technology were used for participants receiving the CoPILOT intervention.

5.2.7 Outcomes

Feasibility indicators were collected for process, resource, management and treatment outcomes throughout the study administration and at completion according to criteria for success set a priori. Table 5.1 provides an overview of feasibility indicators and criteria for success for each of the four feasibility objectives.[79]

Table 5.1 Criteria for Success for Feasibility Indicators

Feasibility Indicator	Measure	Parameter for Success
Process		
Recruitment rate	# of participants recruited	4 participants/month: Total of 32 over 8 months
Consent rate	% of participants consenting	< 10% participant refusal
Retention rate	% of participants with T_2 data collected	Complete T_2 data collection with > 80% of participants
Treatment adherence		
CoPILOT Group		
(12 session protocol)	Number of training sessions attended	> 85% of participants attend 12 sessions
(6 session protocol)		> 85% of participants attend 6 sessions
Control Group		
(12 session protocol)	Number of training sessions attended	> 85% of participants attend 12 sessions
(6 session protocol)		> 85% of participants attend 6 sessions
Resources		
Data collection: Participant & Evaluator Time	Time to complete data collection	> 85% of participants complete T1 ≤ 2hrs. > 85% of participants complete T2 ≤ 1.5hrs.
Collection of HUI3 data	Time to administer	Mean administration is < 10 minutes
	HUI3 pre/post score	Statistically significant T_1 & T_2 change
Trainer Time		
CoPILOT Group		
(12 session protocol)	Time spent on training intervention	Mean time spent/participant is < 20hrs.
(6 session protocol)		Mean time spent/participant is <10hrs.
Control Group		
(12 session protocol)	Time spent on training intervention	Mean time spent/participant is < 20hrs.
(6 session protocol)		Mean time spent/participant is <10hrs.

Feasibility Indicator	Measure	Parameter for Success
Management		
Wheelchair reliability	Downtime due to technical or mechanical issues	> 90% of training sessions experience no wheelchair technical issues
Participant processing time	Time from initial contact to enrolment	Mean time is < 10 days at each site
Treatment administration issues	Qualitative interviews with participants and trainers	Any issues identified can be modified without substantial changes to the protocol
Treatment		
Safety (Skills Training)	Adverse events during skills training	No major injuries or adverse events reported
Safety (Data Collection & Assessment)	Adverse events during assessment	No major injuries or adverse events reported
Treatment response	Two-way ANOVA comparison between groups	A significant difference between groups identified
Dose level response	Two-way ANOVA comparison between groups	At least one training dose sufficient for a treatment effect
Treatment effect & variance	Estimate of effect size and variance for future sample size/power calculations	
Perceived benefit	Qualitative interviews with participants and trainers	Qualitative analysis will inform perceived benefit and clinical significance

To assess treatment outcomes, we collected a variety of data including descriptive measures, measures for a variety of potential confounders, and clinical outcomes of interest. Descriptive measures collected at baseline (T1) included age, sex, diagnosis, previous wheelchair and vehicle driving experience, level of dependence and level of education. A copy of the demographics form is available in Appendix I. Level of dependence was determined as a

function of the need for assistance or use of assistive technologies to complete nine activities of daily living. Details regarding this calculation are available in Appendix M. Additional measures were collected at baseline to describe the sample and as potential confounding variables, including cognition, symptoms of depression, and functional comorbidities. As the population of interest is individuals with mild to moderate cognitive impairment, it was critical to measure this construct. To assess cognition, we used the Montreal Cognitive Assessment (MoCA). The MoCA is a 30 point cognitive assessment which addresses seven cognitive domains and is valid and reliable tool to detect mild to moderate cognitive impairment in older adults.[162] Given the evidence of a significant relationship between depression and cognition in older adults, it was also important to include a measure for mood.[163] Therefore, we used the Geriatric Depression Scale short form (GDS), a 15-item self-report measure which has been validated for use with older adults living in residential care, was included as a measure to evaluate symptoms of depression .[164] The Functional Comorbidity Index (FCI) is a self-report measure which was used as a standardized way to describe the number of comorbidities experienced by the participants in the sample.[165]

The primary clinical outcome of interest was objective PWC skills, which was assessed using the Power Mobility Indoor Driving Assessment (PIDA).[166] The PIDA measures capacity and safety of driving skill in a residential care environment. The PIDA is the only valid and reliable measure available to assess wheelchair skills which includes global skills of speed selection and sharing public spaces, addressing issues of judgement and insight which may be challenged with impaired cognition.[103]

Additional clinical outcomes of interest included subjective wheelchair skills, wheelchair use confidence, wheelchair related goal satisfaction, capacity for divided attention while driving, and

health-related quality of life. To assess subjective wheelchair skills, we used the Wheelchair Skills Test Questionnaire for Powered Wheelchair Users Version 4.2 (WST-Q-P 4.2).[139] The WST-Q-P is a 30-item self-report questionnaire which assesses capacity and performance for PWC skills. Wheelchair use confidence was assessed using the Wheelchair Use Confidence Scale for Powered Wheelchair Users (WheelCon-P) short form.[167] The WheelCon-P short form is an eleven item self-report questionnaire which assesses wheelchair use confidence on a 10-point scale across social and mobility domains. Wheelchair related goal satisfaction was assessed using the Wheelchair Outcome Measure (WhOM).[168] The WhOM requires participants to rate the performance and satisfaction with performance on individually set wheelchair related goals at home and in the community and can be used to assess change in wheelchair related goal satisfaction with performance following training. We used a new measure to assess capacity for divided attention while driving, which has not previously been used for PWC skills. The Wheeling While Talking test (WheelTalk) is an objective measure which requires individuals to complete a maneuverability task with and without an associated cognitive task and measures the impact of the dual task condition on time to complete the task, and errors made.[169] Finally, health-related quality of life (HRQoL) was assessed using the Health Utilities Index 3 (HUI3). The HUI3 measures 8 attributes contributing to HRQoL including vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain.[170] The HUI3 has been validated for use with individuals with dementia.[171] Appendix J outlines all measures, including constructs evaluated and time points for data collection.

5.2.8 Assignment of Interventions

Following enrolment and collection of demographic and baseline data, participants were randomized to one of four groups (CoPILOT 6, CoPILOT12, WSP6, WSP12) using an online

computerized process (www.sealedenvelope.com) which balanced groups using a random permuted blocks design.[172]

5.2.9 Data Collection

5.2.9.1 Feasibility Outcomes

Feasibility data were collected using staff logs, qualitative interviews with the study participants, trainers, evaluators, and co-ordinator, and during collection of clinical outcomes data. Training logs were completed following each training session to collect information on skills practiced, safety or equipment concerns, adverse events, and a plan for the subsequent training session. Throughout the study, staff (coordinator, trainers, and evaluators) recorded challenges with data management and coordination. Semi-structured qualitative interviews with participants (optional), trainers, and the lead evaluator provided further data regarding feasibility outcomes and focus on protocol changes to maximize success in a future RCT. Interview guides are available in Appendix K.

5.2.9.2 Clinical Outcomes

Clinical outcomes comprised one of the treatment indicators and were measured by a trained and masked evaluator at baseline (T1) and following completion of participant training (T2). The primary clinical outcome was objective wheelchair skills, measured by the PIDA. Secondary clinical outcomes were subjective wheelchair skills capacity (WST-Q-P), wheelchair use confidence (WheelCon), wheelchair related goal satisfaction (WhOM), and capacity for divided attention while driving (WheelTalk). The tertiary clinical outcome was health-related quality of life (HUI3). At T1 (pre-randomization), all participants were asked to complete descriptive measures and measures for potential confounders, the WheelCon-P, WhOM, and WST-Q-P 4.2. If participants indicated previous experience with a PWC and reported capacity to

operate the PWC for a variety of basic driving tasks (i.e., driving in a straight line and stopping, turning left and right), they were also asked to complete baseline evaluations for the PIDA and WheelTalk. Participants who had never driven a PWC before did not complete these measures at T1. We considered it unethical to ask a participant to operate a PWC without prior instruction or familiarization. Requiring the completion of these measures at baseline from an individual with no previous instruction would have placed the participant, trainer, and others in the environment at undue risk. Furthermore, a negative experience (e.g., collision) during the evaluation may have impacted the participant's willingness to continue with training. Following training (T2), all participants were asked to complete all clinical outcome measures.

5.2.10 Data Management

Data were collected using electronic and paper-based data forms. All data were de-identified and entered into a secure database by a research assistant trained in data handling. Each variable was checked by a second person for accuracy.

5.2.11 Data Analyses

The sample was described using descriptive variables (e.g., age, sex,) and potential confounding variables (i.e., symptoms of depression, cognition, comorbidities). Measures of central tendency with standard deviation are reported for all continuous demographic, potential confounders, and clinical outcome measures. Frequency and proportion are reported for categorical descriptive variables (i.e., sex, level of education). Feasibility indicators for the four study objectives were evaluated according to parameters for success set a priori. Parameters for success suggest the indicator would be feasible for use in a definitive RCT, and were coded as either successful, requiring minor revision, or requiring major revision. Parameters for success for all indicators are provided in Table 5.1.

5.2.11.1 Objective 1: Feasibility of Study *Processes*

We hypothesized that study processes would be feasible for use in a definitive RCT with minor revisions. To evaluate this hypothesis, we evaluated parameters for success set a priori for rates of recruitment, consent, retention, and treatment adherence.

5.2.11.2 Objective 2: Feasibility of Study *Resources*

We hypothesized that the use of study resources would be feasible for use in a definitive RCT with minor revisions. To evaluate this hypothesis, we evaluated parameters for success set a priori for time required to complete baseline and follow up evaluations (participant and evaluator burden), time required to complete training (trainer burden), time required to collect HUI3 data. For HUI3 data, we also conducted significance testing ($p<0.05$) using a two-way ANOVA to compare main effect of treatment and dose on HUI3 change scores.

5.2.11.3 Objective 3: Feasibility of Study *Management*

We hypothesized that the study management processes would be feasible for use in a definitive RCT with minor revisions. To evaluate this hypothesis, we evaluated parameters for success set a priori for wheelchair reliability (number of sessions impacted by equipment related downtime), and mean participant processing time. We used qualitative interviews with trainers and participants (see Appendix K for interview guides) to evaluate treatment administration issues.

5.2.11.4 Objective 4: Feasibility of Study *Treatment*

We hypothesized that the study treatment would be feasible for use in a definitive RCT with minor revisions. To evaluate this hypothesis, we evaluated parameters for success set a priori for safety of training and data collection/assessment (number of adverse events or major injuries). Treatment and dose level response, and treatment effect were assessed according to

primacy of clinical outcome measures. Perceived benefit was evaluated using qualitative interviews.

For each of the primary, secondary, and tertiary clinical outcomes, we hypothesized that

1) The CoPILOT group would have higher post-treatment scores (or change scores where applicable) than the control group; and,

2) The 12-session group would have higher post-treatment scores (or change scores where applicable) than the 6-session group; and,

3) There would be no interaction effect between treatment group and dose on post-treatment scores (or change scores where applicable.

Results from all clinical outcomes were assessed visually to identify outliers, with testing conducted for normality and homogeneity of variance prior to use in parametric testing. Missing data were imputed using multiple imputation (MI) to create a pooled dataset for ANOVA analysis, accounting for missing post-treatment values for the clinical outcomes. Missing values for the primary clinical outcome (PIDA) are missing for a single participant therefore a Markov Chain Monte Carlo method was used for MI using SPSS 25.[173] Ten imputations were used to create ten imputed datasets, with results pooled for presentation. Data for clinical outcomes are presented for the primary clinical outcome using both the MI dataset and case (listwise) deletion for each analysis as a form of sensitivity analysis on protocol (listwise deletion) and intention to treat (MI). Appendix L shows percent missing data for each clinical outcome.

5.2.11.4.1 Primary Clinical Outcome

Post-treatment PIDA scores were compared for main effects and interactions within and between factors (intervention and training time/dose) using two-way analysis of variance (ANOVA). Two-way ANOVA is an efficient approach to analysis when there are two

categorical independent variables and a continuous dependent variable which allows for analysis of both main effects and the interaction between them.[174] No additional covariates were included in the ANOVA as there were no statistically significant ($p<0.05$) correlations between any of the potential confounding variables and post-treatment PIDA scores, nor compelling theoretical rationale for their inclusion. Statistical significance testing ($p<0.05$) and marginal means with 95% confidence intervals were estimated. While a statistically significant difference between groups was identified as a criterion for success a priori, we also estimated Cohens d, acknowledging the importance of effect sizes in understanding clinical significance in rehabilitation outcomes.

5.2.11.4.2 Secondary Clinical Outcomes

A two-way ANOVA was used to compare post-treatment scores for wheelchair related goal satisfaction with performance (WhOM) home and community sub-scores, self-reported wheelchair skills (WST-Q-P) scores, wheelchair skill confidence (WheelCon-P) social and mobility subscales, and capacity for divided attention while driving (WheelTalk) scores for both intervention and training time factors, and any potential interactions. Significance testing ($p<0.05$) and 95% confidence intervals were estimated. Two-way ANOVA is subject to issues with multiple comparisons, as each variable is compared for both main effects of each factor, and interactions between them (i.e., three comparisons per variable). Cramer et al. suggest two ways to address these comparisons.[175] P-values can be adjusted according to the False Discovery Rate or according to a Bonferroni correction. Adjusted p-values are provided in the results based on a Bonferroni correction.

5.2.11.4.3 Tertiary Clinical Outcome

Change scores for HUI3 data were compared using a two-way ANOVA to evaluate the effect of treatment and dose on health-related quality of life, and interaction between the two factors. Significance testing ($p<0.05$) and 95% confidence intervals were estimated.

5.2.11.4.4 Qualitative Analyses

Analyses of qualitative data related to all feasibility parameters with the exception of perceived benefit were completed using a deductive directed content analysis approach[100], with analyses guided by feasibility parameters described in Table 5.1. Qualitative analyses of data regarding perceived benefit was completed using an inductive analysis, using Braun and Clarke's steps for thematic analysis.[94] Line by line coding was completed with transcripts from interviews with participants and trainers, followed by two rounds of coding, and aggregation into thematic areas.

To address trustworthiness of the data, we used strategies including triangulation of informants and journaling. Qualitative data were provided by trainers, participants, and evaluators, providing multiple perspectives as a form of triangulation. Furthermore journaling was used to record insights and reflexive discussion with study team members on feasibility indicators, challenges, and successes throughout the study process. Interviews were conducted by the study coordinator, who did not have clinical experience. Interpretation was guided by my experience as an occupational therapist with experience in the field.[116] As I had assumptions regarding the potential positive effect of the intervention, quotes are provided from all participant groups and types of informants.

5.2.12 Informed consent.

As this study included individuals who experience memory impairment, legal consent was signed by the participant and/or a substitute decision maker, and an ongoing process of consent monitoring was used.[176] As in standard clinical practice, the trainer provided a reminder to the participant at the outset of each training session about the process of the study, and sought verbal consent to proceed. Any concerns with consent or participant refusal were documented by trainers in the training log.

5.3 Results

5.3.1 Participants

Twenty-five participants were enrolled in the study. Participant demographics and clinical characteristics at baseline can be seen in Table 5.2 by group (CoPILOT 6, CoPILOT 12, WSP 6, and WSP 12). For each of the demographic characteristics, dose is represented by the rows, and treatment by columns. Therefore, each cell represents a single group. Marginal values (i.e., total per dose across both treatment groups, or total per treatment across dosages) are represented in the 'All' rows and columns. To assist in reading the table, a key to the cells and margins has been provided at the top.

Table 5.2 Participant Characteristics at Baseline (n=25)

	Dose	CoPILOT (n=13)	WSP (n=12)	All
Key	6	*CoPILOT6*	*WSP6*	*All 6*
	12	*CoPILOT12*	*WSP12*	*All 12*
	All	*All CoPILOT*	*All WSP*	
Sex (Female)	6	5	2	7
Frequency	12	4	2	6
	All	9	4	13
Age	6	65.9	69.3	67.5
Mean		*10.8*	*14.7*	*12.3*
SD	12	72.4	67.3	69.9
		5.8	*12.0*	*9.4*
	All	68.9	68.3	68.6
		9.2	*12.8*	*10.8*
Level of	6	10.0	8.0	9.1
Dependence[1]		*4.8*	*5.0*	*4.8*
Mean	12	12.8	8.8	10.8
SD		*1.7*	*4.0*	*3.6*
	All	11.3	8.4	9.9
		3.9	*4.4*	*4.3*
MOCA	6	17.1	16.6	16.8
Mean		*4.8*	*4.5*	*4.5*
SD	12	14.8	17.9	16.4
		8.1	*3.8*	*6.2*
	All	16.0	17.2	16.6
		6.3	*4.0*	*5.3*
Geriatric	6	5.0	5.8	5.4
Depression		*2.4*	*2.6*	*2.5*
Scale	12	7.2	4.3	5.8
Mean		*5.2*	*1.9*	*4.0*
SD	All	6.0	5.1	5.6
		3.9	*2.3*	*3.2*
Functional	6	5.0	3.8	4.5
Comorbidity		*3.1*	*2.6*	*2.8*
Index	12	4.5	5.2	4.8
Mean		*1.5*	*2.6*	*2.0*
SD	All	4.8	4.5	4.6
		2.4	*2.6*	*2.4*

[1]Level of Dependence is calculated based on need for assistance for 9 activities of daily living. Lowest score (least assistance) is 0, highest possible score is 18. Details of calculation available in Appendix M.

Participants' primary diagnoses were varied, including stroke (n=8), neuromusculoskeletal conditions (n=4), neurological conditions (n=3), cancer, epilepsy, spinal cord injury, acquired brain injury, chronic obstructive pulmonary disorder, osteoporosis, and amputation (n=1 per remaining condition). Three participants did not know their primary diagnosis. The majority (n=12) of participants had completed high school, with the remaining having less than high school (n=2), college (n=2), or undergraduate education (n=4). Education data were missing for five participants due to a problem with the electronic data forms. The CoPILOT12 group was older, with higher levels of dependence and depression, and lower levels of cognition than the other groups, however, there were no statistically significant differences between individual group or marginal means for any baseline characteristic. The mean WSP12 score on the Geriatric Depression Scale was lower than the published cut score for mild depression (score of 5-8 is indicative of mild depression),[177] where the other three groups were at or above this score. The mean CoPILOT12 score for cognition was lower than the remaining three groups, which may be clinically significant. There were no other potentially clinically significant differences between groups.

5.3.2 Feasibility Indicators

Feasibility indicators were evaluated across the four feasibility objectives: process, management, resource, and treatment. Results for each objective are drawn from both quantitative and qualitative analyses and described by type of indicator below.

5.3.2.1 Objective 1: Study Processes

Study processes are concerned with recruitment, including eligibility, consent, and refusal, retention, compliance with intervention, and the use of study questionnaires and data

collection tools.[79] Three of seven indicators met the hypothesized a priori criteria for success (retention rate, and treatment adherence for CoPILOT6 and COILOT12 groups). Results are shown in Table 5.3 with additional details provided in the text below.

Table 5.3 Feasibility Outcomes: Process Indicators (n=25)

Feasibility Indicator	Results *Criteria for Success (set a priori)*	Feasible?		
		Yes	Minor Revision	Major Revision
Recruitment Rate	1 participant/month *4 participants/month*			✗
Consent Rate	13% participant refusal *<10% participant refusal*		✓	
Retention Rate	96% of participants completed T2 data collection *>80% of participants complete T2 data collection*	✓		
Treatment Adherence[1] (n=24[2])				
CoPILOT6	5/6 participants attended 6 sessions *85% of participants attend 6 sessions*	✓		
CoPILOT12	3/6 participants attended 12 sessions *85% of participants attend 12 sessions*			✗
WSP6	5/6 participants attended 6 sessions *85% of participants attend 6 sessions*	✓		
WSP12	4/6 participants attended all scheduled sessions *85% of participants attend 12 sessions*			✗

Participants were recruited at a rate of 1 participant per month, for a total of 25 participants, which failed to meet the hypothesized standard set a priori for 4 participants per month. Recruitment was conducted in six residential care sites across two health authorities. Sites which did not allow PWCs were not included, therefore recruitment could not occur at all potential facilities. One site which was approached declined to participate due to clinician

workload. Initial screening for eligibility was completed by occupational therapists working in each of the sites. Of those who were referred and were ineligible, the primary reason was an inability to communicate in English for the purposes of assessment and training. See the Consort Diagram in Figure 3 for progress of participants from enrollment to analyses.

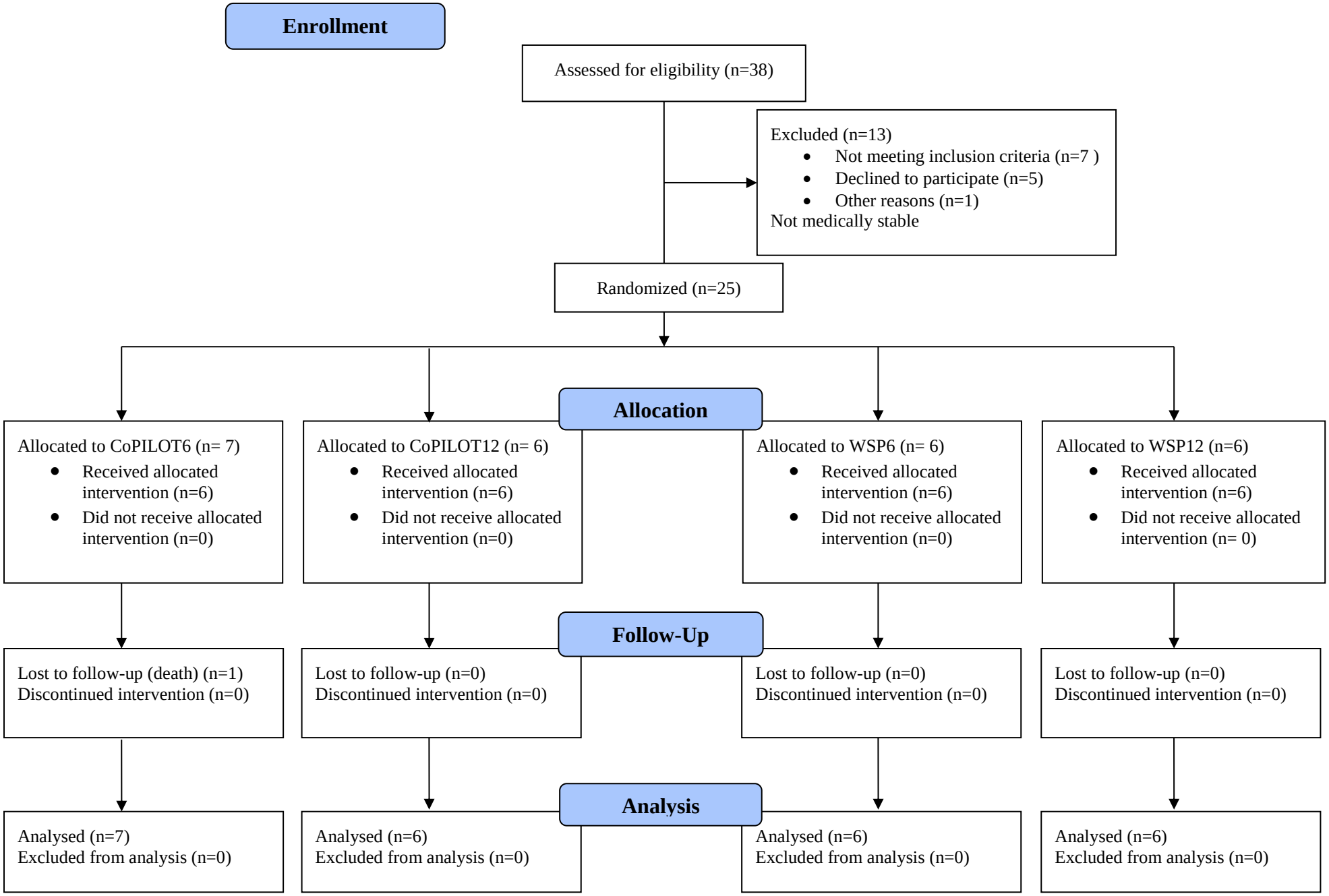


Figure 5.3 Consort Diagram

A total of 30 eligible individuals were approached to participate and 25 consented to be part of the study, falling below the a priori set threshold of less than 10% refusal for success. Reasons for refusal included not being interested in learning to use a PWC or being too busy to accommodate training. No concerns were identified by trainers with process consent obtained prior to each training session.

Of 25 participants who consented to participate, there was one withdrawal as a result of death from influenza. This withdrawal occurred after the collection of baseline measures, but prior to the start of training. Retention rates met the criteria defined a priori for 90% retention of participants to T2 data collection as seen in Table 5.4.

The criteria for success for treatment adherence was met for the 6 session protocols (both CoPILOT and WSP) but was not met for either of the 12 session protocols. The 12-session protocol was challenging to schedule due to the higher intensity of training (4 sessions/week vs. 3 sessions/week). The reasons for missed training sessions included feeling unwell (including flu outbreaks), sleeping, unable to be located, pain, fatigue, and difficulty scheduling additional lessons due to participant or trainer schedules.

Baseline data collection included questionnaire-based measures for all participants, and objective PWC use measures for participants who had previous experience using a PWC (n=9). As a result, objective measures were not collected for all participants and it is not possible to evaluate pre-post change in outcomes. Evaluators reported difficulty for participants in completing a variety of self-report measures, particularly those which were more abstract to understand (e.g., confidence) or required reporting capacity to complete unfamiliar tasks which they had not tried previously (i.e., subjective wheelchair skills). Furthermore, as many

participants did not have full or partial use of their dominant hand for writing, the use of the MoCA presented specific challenges, particularly for those tasks which require writing or drawing. Participants also had trouble identifying wheelchair related goals in both home and community. For objective measures, 11 participants declined to complete the dual task component of the WheelTalk test.

5.3.2.2 Objective 2: Study Resources

Resource indicators are study factors which require staff or participant resources, including time, and include time required for evaluations and training for study staff and participants, availability and readiness of study equipment.[79] Seven of ten resource indicators set a priori were feasible for implementation. Each of these is described in Table 5.4.

Table 5.4 Feasibility Outcomes: Resource Indicators

Feasibility Indicator	Result *Criteria for Success (set a priori)*	Feasible? Yes	Minor Revision	Major Revision
Data Collection: Participant and Evaluator Time[3] (n=19[4])				
T1	16/19 participants completed in <2hrs. *>85% participants complete <2hrs.*	✓		
T2	17/19 participants completed in <1.5hrs. *>85% (5/6) participants complete <1.5hrs.*	✓		
Collection of HUI3 Data[2]	Statistically significant T2-T1 change for WSP12 group only (p=0.032) *Statistically significant T2-T1 change*	✓		✗
T1[4]	Mean administration time was 7.14 minutes *Mean administration time is <10 minutes*	✓		
T2[4]	Mean administration time was 7.55 minutes *Mean administration time is <10 minutes*	✓		
Trainer Time				
CoPILOT6	Mean time spent per participant was 10.6hrs. *Mean time spent per participant is <10hrs.*		✓	
CoPILOT12	Mean time spent per participant was 20.2hrs. *Mean time spent per participant is <20hrs.*		✓	
WSP6	Mean time spent per participant was 9.63hrs. *Mean time spent per participant is <10hrs.*	✓		
WSP12	Mean time spent per participant was 15.50hrs. *Mean time spent per participant is <20hrs.*	✓		

[1]85% treatment adherence in groups of six is equivalent to 5.1 individuals. Criteria for success rounded to include 5/6 participants as equivalent to 85%. [2]One participant did not complete any training due to death from influenza and is not included in this analysis.[3]85% of 19 participants is equivalent to 16.15 individuals. Criteria for success rounded to include 16/19 participants as equivalent to 85%. [4]Due to technological errors, total evaluation time data was not captured for 6 participants at T1 and 5 participants at T2.

Data collection overall times met the criteria for success set a priori as 2hrs. for baseline data collection, and 1.5hrs. for T2 data collection. However, despite meeting the overall criteria for time, additional burden was placed on evaluators and participants as 8 individuals required more than one session to complete T1 data collection, and 4 participants required 2 sessions to complete T2 data collections.

CoPILOT training times slightly exceeded the a priori criteria for success as seen in Table 5.4, while WSP protocols met the criteria for success. Additional time for CoPILOT training sessions was reported by trainers to be related to technology management, and difficulty finding clinical staff to assist with participant transfers to the wheelchair.

5.3.2.3 Objective 3: Study Management

Management indicators relate to human, equipment, and data management concerns, including reliability of study technology, time required for participant processing, treatment administration, and data management.[79] One of three indicators met the a priori criteria for success, as seen in Table 5.5.

Table 5.5 Feasibility Outcomes: Management Indicators

Feasibility Indicator	Results *Criteria for Success (set a priori)*	Feasible? Yes	Minor Revision	Major Revision
Wheelchair reliability	85.85% of training sessions experienced no wheelchair technical issues *>90% of training session experience no wheelchair technical issues*			✗
Participant processing time	Mean time overall from initial contact to enrolment was 6.48 days. One site exceeded 10 days (Mean: 13.33 days). Each of the remaining 5 sites did not exceed 10 days *Mean time from initial contact to enrolment is <10 days at each site*		✓	
Treatment administration issues	No issues were identified with treatment administration which require substantial changes to the protocol *Any issues identified can be modified without substantial changes to the protocol*	✓		

Technical issues were encountered in approximately 15% of training sessions and were limited to the CoPILOT protocols. Technical issues generally fell into one of three categories: difficulties with the wheelchair (poor PWC charging and battery performance), difficulty starting up the CoPILOT system or maintaining connection with the CoPILOT remote, and a technical glitch with the CoPILOT system resulting in the wheelchair motors disengaging and causing an audible “clicking” noise accompanied by the wheelchair rolling downhill slightly when positioned on a slope. Each of these technical concerns was resolved by the study team, and there were no reports of adverse events associated. However, two training sessions were missed as a result of these concerns.

Overall, participants were enrolled in the study within one week (6.48 days) from initial contact, which met the a priori criteria for success. However, one site experienced longer than average time, with a mean processing time of 13.33 days. Mean time from enrolment to baseline evaluation was 21.76 days. However, two participants each exceeded 100 days (191 and 119 days respectively) due to difficulties with participant scheduling and trainer availability, therefore baseline evaluation was re-done prior to treatment. Excluding these participants, the mean time from enrolment to baseline was 10.17 days. Mean time from randomization to treatment was 9.00 days; mean time from the end of training to T2 evaluation was 5.54 days.

Data were initially collected for both descriptive and clinical outcomes, as well as ongoing training data, using Fluid Surveys™ (online survey tool). Technical challenges with the survey tool for the first six participants resulted in minor loss of data related to outcome measure timing, education level, and incorrect coding of trainer data. Changes were made to the online system to resolve concerns with trainer data, and paper-based forms were added to provide redundancy and ensure no further loss of data due to the use of an online system. Electronic data collection was transferred to Qualtrics™ for participants 7 through 25 due to a change in university contracts. No further loss of data was experienced following this shift.

5.3.2.4 Objective 4: Treatment

Treatment indicators include treatment and dose level responses, effect, and variance, safety of treatment or intervention, and perceived benefit.[79] Each of these indicators is described in Table 5.6, with additional clinical outcomes described in the tables and sections below. Five of six treatment indicators met the a priori criteria for success.

Table 5.6 Feasibility Outcomes: Treatment Indicators

Feasibility Indicator	Results *Criteria for Success (set a priori)*	Feasible? Yes	Minor Revision	Major Revision
Safety (Skills Training)	Two adverse events reported with no major injuries and no impact on training *No major injuries or adverse events reported*	✓		
Safety (Data Collection & Assessment)	No major injuries or adverse events reported. *No major injuries or adverse events reported*	✓		
Treatment Response	No statistically significant difference between groups. *A significant difference between groups identified*			✗
Dose Response	Training doses of 6 and 12 sessions both sufficient for a treatment effect *At least one training dose sufficient for a treatment effect*	✓		
Treatment Effect & Variance	See Tables 5.10 and 5.11 for effect sizes for each group and outcome *Estimate of effect size and variance for future sample size/power calculations*	✓		
Perceived Benefit	Qualitative results presented in text. *Qualitative analysis will inform perceived benefit*	✓		

5.3.2.4.1 Clinical Outcomes

The means per group and marginal means at T2 for the primary, secondary, and tertiary outcomes are presented in Table 5.7. Means for individual groups (i.e., CoPILOT6, CoPILOT 12, WSP6, and WSP12) are based on a group size of six, while marginal means are based on a group size of 12, unless otherwise indicated by a superscript number. To assist in interpretation

of the table, a key is provided in the top to identify individual and marginal means (bold) for each cell.

Table 5.7 Clinical Outcomes: Descriptive Statistics

	CoPILOT Mean (SD)	WSP Mean (SD)	All Mean (SD)
Key			
6 sessions	*CoPILOT6*	*WSP6*	***All 6***
12 sessions	*CoPILOT12*	*WSP12*	***All 12***
All	***All CoPILOT***	***All WSP***	*All participants*
Primary Clinical Outcome: Power Mobility Indoor Driving Assessment (T2)			
6 sessions	79.3(11.4)	83.6 (12.4)	**81.4 (11.6)**
12 sessions	76.0 (15.9)	88.6 (7.4)	**82.3 (13.5)**
All	**77.7 (13.3)**	**86.1 (10.1)**	81.9 (12.3)
Secondary Clinical Outcomes			
Wheelchair Skills Test Questionnaire for Powered Wheelchair Users: Capacity (T2)			
6 sessions	35.0 (10.7)	33.0 (18.3)	**34.0 (14.3)**
12 sessions	29.3 (12.5)	41.5 (7.4)	**35.4 (11.7)**
All	**32.2 (11.5)**	**37.3 (14.0)**	34.7 (12.8)
Wheelchair Use Confidence Scale for Powered Wheelchair Users: Mobility Subscale (T2)			
6 sessions	77.6 (15.5)	68.2 (32.2)	**72.9 (24.6)**
12 sessions	57.7 (12.1)	77.3 (18.2)	**67.5 (17.9)**
All	**67.7 (16.9)**	**72.7 (25.4)**	70.2 (21.2)
Wheelchair Use Confidence Scale for Powered Wheelchair Users: Social Subscale (T2)			
6 sessions	48.5 (17.1)	48.7 (28.9)	**48.6 (22.6)**
12 sessions	45.0 (21.6)	53.7 (24.1)	**49.3 (22.3)**
All	**46.8 (18.7)**	**51.2 (25.4)**	49.0 (22.0)
Wheeling While Talking Test (T2)*			
6 sessions	61.20 (-)[1]	48.0 (51.5)[5]	**50.3 (46.4)[6]**
12 sessions	13.5 (37.6)[3]	-7.8 (8.9)[3]	**2.9 (27.1)[6]**
All	**25.7 (39.2)[4]**	**27.0 (48.7)[8]**	26.6 (43.9)[12]
Wheelchair Outcome Measure: Home (Change Scores)			
6 sessions	18.0 (28.6)[4]	45.4 (67.9)[5]	**33.2 (53.1)[9]**
12 sessions	8.2 (55.8)[5]	57.5 (71.1)[4]	**30.1 (64.2)[9]**
All	**12.6 (43.5)[9]**	**50.8 (65.1)[9]**	31.7 (57.2)[18]

	CoPILOT Mean (SD)	WSP Mean (SD)	All Mean (SD)
Wheelchair Outcome Measure: Community (Change Scores)			
6 sessions	116.0 (64.8)[5]	102.5 (91.7)[4]	**110.0 (72.8)[9]**
12 sessions	41.5 (53.5)[4]	35.2 (141.9)[5]	**38.0 (105.6)[9]**
All	**82.9 (68.7)[9]**	**65.1 (120.3)[9]**	74.0 (95.5)[18]
Tertiary Clinical Outcome: Health Utility Index 3 (Change Scores)			
6 sessions	0.14 (0.19)[5]	-0.15 (0.30)	**-0.02 (0.28)**
12 sessions	0.03 (0.16)	0.22 (0.19)	**0.12 (0.19)**
All	**0.08 (0.17)[11]**	**0.04 (0.30)**	0.06 (0.25)

*Lower scores are better

Scores per group ranged from 76.04% to 88.63% (see Table 5.7). A two-way analysis of variance (ANOVA) was conducted to determine if there were differences between groups or an interaction between treatment (COPILOT or WSP) and dose (6 or 12 sessions). There were two outliers, assessed visually as being greater than 1.5 box-lengths from the edge of the boxplot, both outliers were retained for data analyses using intention to treat analysis.[178] Data was tested for normality using the Shapiro-Wilk Test ($p<0.05$) and found to be normally distributed.

5.3.2.4.2 Imputed Data Analyses: Primary Outcome

The estimated marginal means (EMMs) of the PIDA scores for each group are presented in Table 5.8. There was no statistically significant difference between treatment groups, rejecting the null hypothesis set a priori. Comparison of EMMs for PIDA scores across the two doses (6 sessions and 12 sessions) also produced no significant difference between treatment groups, again rejecting the null hypothesis set a priori. The two-way ANOVA found no statistically significant interaction between the factors, confirming the hypothesis set a priori. Table 5.8 provides details of the ANOVA analyses for both the MI dataset and the original dataset with case (listwise) deletion. Effect sizes are reported as *d* (Cohen's d) with negative effect sizes

bolded and representing areas where WSP exceeded CoPILOT means, or 6 sessions exceeded 12 session means.

Table 5.8 Estimated Marginal Means for Main Effects and ANOVA Results for the PIDA (Primary Clinical Outcome)

	Multiple Imputation (n=25)				Case Deletion (n=24)			
Factor	EMM (SE)	95% CI	ANOVA	Effect	EMM (SE)	95% CI	ANOVA	Effect
CoPILOT	77.8 (3.3)	70.9, 84.6	*F*=3.075 *p*=0.094	$\eta_p^{2\,=}$ 0.128	77.663 3.506	70.350, 84.975	*F*=2.896 *p*=0.104	$\eta_p^{2\,=}$ 0.126
WSP	86.1 (3.4)	79.0, 93.2		***d*= 0.766**	86.099 3.506	78.786, 93.411		*d*= 0.759
6 sessions	81.5 (3.3)	74.7, 88.4	*F*=0.029 *p*=0.866	$\eta_p^{2\,=}$ 0.001	81.452 3.506	74.113, 88.738	*F*=0.034 *p*=0.856	$\eta_p^{2\,=}$ 0.002
12 sessions	82.3 (3.4)	75.2, 89.5		*d*= 0.032	82.336 3.506	7.024, 89.649		*d*= 0.045
	Adjusted R^2=0.032				Adjusted R^2=0.027			

$\eta_p^{2\,=}$ Partial η^2; *d*=Cohen's *d*

5.3.2.4.3 Imputed Data Analysis: Secondary and Tertiary Outcomes

Analyses using two-way ANOVA were conducted for the MI dataset for each of the secondary and tertiary clinical outcome measures and can be found in Table 5.9. There were no statistically significant differences between treatment or dose groups for any of the secondary or tertiary outcome measures, rejecting all hypotheses set a priori. There was only one significant interaction effect. The HUI3 change scores demonstrated a significant interaction effect for treatment and dose (p=0.006), rejecting the hypothesis set a priori. Effect sizes are reported as *d*

(Cohen's d) with negative effect sizes greater than -0.2 (small effect) are bolded and representing areas where WSP exceeded CoPILOT means, or 6 sessions exceeded 12 session means.

Table 5.9 Estimated Marginal Means for Main Effects and ANOVA results for Secondary Clinical Outcomes (WST-Q-P, WheelCon, WhOM) and Tertiary Clinical Outcome (HUI3)

Factor	EMM	Std. Error	95% Confidence Interval	ANOVA Sig.	Effect	2-way ANOVA
Wheelchair Skills Test Questionnaire for Powered Wheelchair Users (WST-Q-P)						
CoPILOT	32.2	3.5	24.9, 39.4	F=1.03	η_p^2=0.047	F=1.997
WSP	37.3	3.6	29.7, 44.8	p=0.32	***d*=0.444**	p=0.172
6 sessions	34.0	3.5	26.8, 41.2	F=0.08	η_p^2=0.004	η_p^2 =0.087
12 sessions	35.4	3.6	27.9, 42.9	p=0.78	d=0.127	
Wheelchair Use Confidence Scale for Powered Wheelchair Users: Mobility Subscale						
CoPILOT	67.2	5.7	55.4, 79.1	F=0.450	η_p^2=0.021	F=2.923
WSP	72.7	5.9	60.4, 85.0	p=0.510	***d*= 0.293**	p=0.102
6 sessions	72.4	5.7	60.6, 84.3	F=0.363	η_p^2=0.017	η_p^2 =0.122
12 sessions	67.5	5.9	55.2, 79.8	p=0.553	***d*=0.263**	
Wheelchair Use Confidence Scale for Powered Wheelchair Users: Social Subscale						
CoPILOT	46.8	6.3	33.6, 60.0	F=0.229	η_p^2=0.011	F=0.222
WSP	51.2	6.6	37.5, 64.8	p=0.637	***d*=0.211**	p=0.642
6 sessions	48.6	6.3	35.5, 61.8	F=0.006	η_p^2=0.000	η_p^2 =0.010
12 sessions	49.3	6.6	35.7, 63.0	p=0.939	d=0.000	
Wheelchair Outcome Measure: Home						
CoPILOT	17.6	13.6	-10.7, 40.0	F=2.027	η_p^2=0.088	F=0.168
WSP	45.6	14.1	16.2, 75.1	p=0.169	***d*=0.621**	p=0.686
6 sessions	33.1	13.6	4.7, 61.4	F=0.021	η_p^2=0.001	η_p^2 =0.008
12 sessions	30.2	14.1	0.8, 56.6	p=0.885	d=0.063	
Wheelchair Outcome Measure: Community						
CoPILOT	78.6	22.5	31.9, 125.4	F=0.120	η_p^2=0.006	F=0.000
WSP	67.4	23.3	18.9, 115.9	p=0.732	d=0.155	p=0.987
6 sessions	98.9	22.4	52.1, 145.6	F=2.549	η_p^2=0.108	η_p^2=0.000
12 sessions	47.2	23.3	-1.4, 95.7	p=0.125	***d*=0.696**	

Factor	EMM	Std. Error	95% Confidence Interval	ANOVA Sig.	Effect	2-way ANOVA
Wheeling While Talking[1]						
CoPILOT	26.2	7.9	9.7, 42.7	F=0.001	η_p^2=0.000	F=1.059
WSP	8.2	8.2	9.5, 43.7	p=0.971	d=0.000	p=0.315
6 sessions	38.1	7.9	21.6, 54.6	F=4.181	η_p^2=0.166	η_p^2=0.048
12 sessions	14.7	8.2	-2.4, 31.8	p=0.054	d=0.892	
Health Utility Index 3						
CoPILOT	0.10	0.06	-0.02, 0.22	F=0.542	η_p^2=0.025	F=9.289
WSP	0.04	0.06	-0.09, 0.16	p=0.470	d=0.320	p=0.006
6 sessions	0.01	0.06	-0.11, 0.13	F=1.851	η_p^2=0.081	η_p^2=0.370
12 sessions	0.12	0.06	0.00, 0.25	p=0.188	**d=0.594**	

[1]Lower scores are better
Abbreviations: CoPILOT: Intervention, WSP: Control, EMM: Estimated Marginal Means, ANOVA: Analysis of Variance; η_p^2 = Partial η^2; d=Cohen's d

5.3.2.4.4 Qualitative Results: Perceived Benefit

Perceived benefit was assessed through qualitative interviews with participants and trainers. Fifteen participants chose to participate in the optional interview following their training. Of these, 7 received CoPILOT training and 8 received WSP training, while six of those interviewed received 12 sessions of training, and nine received 6 sessions. Trainers provided feedback throughout the study through training reports and a qualitative interview. Two themes were identified in the data: The first theme "See possibilities driving," is related to the use of shared control in PWC training, while the second theme, "More complicated than driving a bicycle," relates to challenges learning and the need for adequate training time.

The first theme, "See possibilities driving," highlights how the shared control remote was or could be used in training to enhance the learning experience. Participants in the CoPILOT group were generally positive about the use of the remote during their training. When asked what

made their training easier, 4 of the participants specifically cited the remote, indicating it helped them see “possible driving” skills, allowed the trainer to “take over if I make a mistake,” or “made it easier… and was a lot of help for me.” One participant specifically commented on how the use of the remote provided an environment with “no pressure.” Those in this group generally commented they felt safe throughout the intervention. When asked what the trainer did to help her feel safe during the training, one participant specifically noted “the remote. [With] the remote, I feel safe.” For CoPILOT trainers, the shared control “allowed me to give the participant more independence to perform tasks without being apprehensive about safety, because I knew that I could always intervene.” The experiences of both the participants and the trainers using the shared control remote speaks to perceived benefit of a safe and supported learning environment.

For those in the WSP group, participants commented regularly on qualities of their trainer which helped them to learn the necessary skills. For example, one participant commented on how the trainer “always asked my opinion, and always asked me my goals,” highlighting the importance of goal directed learning. Four of the participants specifically commented on the trainer’s explanations as being helpful for their learning. When asked what the trainer could have done differently to help them learn, one participant noted “it would have been interesting had she been in her own power chair, ‘cause she could say “this is what we’re gonna do” and I just have to copy rather than come up with my own way to execute the move.” He also indicated choosing not to attempt a skill (ascending a curb) as he was not convinced the chair would be able to do it, despite the trainer telling him it was possible. Three participants also commented on challenging experiences where they did not feel safe. The first noted there was a “time lag” when stopping

the chair, where the trainer indicated they could remove their hand from the joystick to stop, “but when it took those 2-3 seconds, I was already in contact with the table.” The same participant also spoke about not feeling generally safe during their training and feeling as though they were a danger to others in the hallway. A different participant spoke about their fear with attempting to navigate a gravel surface, indicating they were “scared I’m gonna flip over, and I feel like my life’s in danger.” When the chair did get stuck, the trainer was required to push the chair out of the gravel to reposition the participant. In each of cases, the trainer would have been able to demonstrate these skills using the shared control remote, and reduce any anxiety associated with trying them for the first time.

The second theme, “More complicated than driving a bicycle,” highlights the challenges of learning to operate a PWC. Participants in both groups commented on the difficulty of learning how to back up (overall) and get in and out of tight spaces. One participant commented “to back up from the washroom is the most difficult… because there are installations … and also because of the small room,” while another noted that backing up “was confusing, even though I like to relate to what I used to do [driving heavy machinery].” Another participant highlighted the challenging in becoming “…more alert, and to be aware of your surroundings…. In case you had to stop, to be able to be alert enough to stop the chair in time in case an accident was to happen.” Developing the awareness of the environment and the chair is one of the key skills in PWC training and requires time in the chair practicing. As one participant noted, “it’s more complicated than driving a bicycle, and you need time to practice to get accustomed to it.” While participants each noted their own areas of difficulty, several others also commented on the importance of practice. In fact, five participants interviewed specifically felt they required more

practice before they would feel like an independent driver. Of these, four of the participants had only received six sessions of training.

5.4 Discussion

The primary objective the study described in this chapter was to understand the feasibility of study methods and procedures for a definitive RCT. The results from this research highlight three key challenges, each of which will be discussed below: conducting research with older adults, integrating novel technologies into clinical research, and research using complex rehabilitation and technology interventions. Five of the 26 feasibility indicators reported in the results require substantial changes prior to proceeding with a subsequent trial, notably recruitment, treatment adherence, wheelchair reliability, treatment response, and change in HUI3 data. Opportunities for refinement in each of these areas are discussed below. Moreover, consideration must be given to the choice of outcome measures, including further validation of existing measures for this population.

5.4.1 Conducting Rehabilitation Research with Older Adults

Our study was challenged by many of the same issues reported in the literature on engaging older adults in research – specifically recruitment, the use of self-report measures, participant burden, and treatment adherence.[179,180] Recruitment was among the most substantial challenge encountered during this study. One potential reason for this challenge is our experience with gatekeepers in the residential care environment. Carroll and Zajicek describe gate-keeping as one of the key limiting factors in clinical trials with older adults.[181] We were able to enroll participants from six sites, each of which required the engagement of a facility manager, as well as occupational therapists who could serve as conduits to participants who were eligible for the

study. Recruitment was limited by the number of sites who permit PWC use in the facility, the workload capacity of the liaising occupational therapists, and equipment available to the clients following completion of the study. Those sites with the highest turnover, where there was a higher expectation for on-site clinicians to provide assessment and training for new residents, had the highest rates of recruitment. However, therapists were hesitant to refer participants to the study if there was no possibility of providing them with a PWC at completion of the training, whether due to a lack of equipment, or because of environmental concerns including challenging behaviours. A future study which was integrated into the care environment, where on-site clinicians were providing training may address this challenge as it would be better integrated within their clinical practice. To do so would require clear communication about the aims of the study, and continued engagement to develop cooperative working relationships with these individuals.[182] It may also be necessary to adjust expectations for recruitment in these sites, or identify sites with the highest rates of patient turnover.

The use of self-report measures for depression, functional comorbidities, wheelchair related goals, wheelchair confidence, perceived wheelchair skills, and health utility also presented challenges with an older adult population. Some of the items from these measures were difficult for the participants to understand conceptually. Evaluators questioned the accuracy of responses provided by the participants, particularly where the participant's response was obviously incorrect (e.g., reported independence walking when they were unable to walk). While the reliability of outcomes including the Geriatric Depression Scale has been evaluated for older adults with dementia and cognitive impairments,[183] the self-reported wheelchair related outcome measures have not been validated for this population. Individuals with cognitive impairment may

underreport functional limitations, and there is a link between inaccurate self-reports and depression.[184,185] Given the inclusion of individuals with mild to moderate cognitive impairment, and results in our study suggesting over half of the sample experienced probable depression,[177] this is worthy of consideration. Future studies should consider establishing reliability and validity for the subjective and objective wheelchair related assessments (WST-Q-P, WheelCon-P, WhOM, WheelTalk) prior to use or removing them from the study for this population.

Decreasing participant burden was identified in a systematic review as one of the key factors which should be considered to increase inclusion of complex older adults in RCTs.[186] In the CoPILOT study, participants completed a baseline and follow-up assessment and were given the chance to participate in an optional interview. Several participants required the baseline evaluation to be split into two – one session addressing paper-based forms, and one requiring objective testing. This resulted in additional burden on both the participants and evaluators. In the follow up sessions, two sessions were completed only when a participant was too fatigued to complete the entire evaluation in one session. For those preclinical dementia or mild cognitive impairments sustained attention is known to be a challenge.[187] It is therefore worth considering whether these assessments should be split a priori in the future to ensure fatigue and attention do not influence the results of the evaluation.

Participant burden can also be considered in the context of number and length of sessions. Treatment adherence proved to be challenging, particularly for participants in the 12-session group (4x/week for 3 weeks). Missed sessions were often related to participant wellness or difficulty scheduling in a busy residential care environment. In a study of manual wheelchair users receiving training in residential care, similar concerns were cited – residents had difficulty

scheduling sessions due to illness, and the busy residential care environment.[188] Difficulties with treatment adherence are also supported by a systematic review suggesting challenges with treatment adherence may be related to the number and length of sessions, while poor health was cited as a common reason for refusal or drop out.[179] In the CoPILOT study, adherence was not a challenge for the 6-session group – this group had only 3 sessions per week, allowing flexibility to reschedule if a training session was missed. Training schedules were based on Hall and Partnoy's evaluation of two PWC training protocols, where they did not report challenges with adherence.[41] However, in Hall and Partnoy's evaluation, all individuals were trained by clinicians working in the residential care environment which may have provided the necessary flexibility. Providing flexibility within the training schedule and the use of trainers already working in the residential care environment would ensure participants are able to complete the trial as planned.

5.4.2 Integrating Novel Technologies into Clinical Research

We faced several challenges related to the integration of novel technologies into clinical research, including both the CoPILOT shared control technology and the use of electronic data forms. The resource indicator for the CoPILOT protocol was specifically challenged by the additional time required for the management of prototype shared control equipment. While the rationale for conducting feasibility studies includes potential challenges with equipment,[79] literature on health technology development largely falls under the category of usability trials which include questionnaires, interviews and usability tests.[189] In fact, a systematic review on the efficacy and usability of assistive technologies for individuals with cognitive impairments found that the efficacy of assistive technologies is not sufficiently studied using clinical trials.[190] This

may be due to the challenges of integrating technology into a new setting, or having study personnel in the clinical environment who are equipped to take on the range of technological challenges presented by a prototype technology. It is possible that a primary role of a feasibility trial for studies utilizing health technologies is to identify challenges in the integration of novel technologies into clinical environments, and for establishing a bridge between usability and clinical trials.

In terms of data management, the initial plan to collect data only via a computerized data collection survey system was revised part way through the study due to minor data loss associated with evaluation time and mis-recorded dates for data collection. This raised concerns about potential other data loss, and we elected to use of both electronic and paper-based forms for the remainder of the study ensure complete data collection. The use of electronic data collection is attractive for clinical trials, as it eliminates the need for data entry from paper based forms by study personnel, reducing both costs and required time, and may keep more accurate records.[191] In the absence of recommendations on the use of electronic forms for data collection , it may be worth considering the use of two methods of data collection until the reliability of these systems can be established.

5.4.3 Research Methods for Complex Rehabilitation and Technology Interventions

The CoPILOT intervention includes several areas of complexity described by the Medical Research Council (MRC) in their guidelines on Developing and Evaluating Complex Interventions, including interactions between components of the intervention, difficulty of behaviours of those receiving the intervention, number and variability of outcomes, and the degree of flexibility or tailoring in intervention delivery.[71] We did not find statistically

significant differences between treatment groups for either the intervention or the dose for any of the primary or secondary clinical outcomes. Furthermore, we found a moderate to large negative effect of the CoPILOT intervention versus the control. This effect is clinically significant as it suggests individuals who received CoPILOT training had worse outcomes than those who received the WSP control protocol. In the following paragraphs, I will present reasons why this may have been the case, I will also highlight the role challenges posed by complex interventions, heterogenous populations, and the use of appropriate outcome measures may have played in these findings,[74] calling into question the appropriateness of the use of a randomized controlled trial.

While there were no statistically significant differences between groups at baseline, baseline scores suggest there may have been meaningful clinical differences in age, cognition, and depression between groups not identified in statistical analyses due to the small sample sizes. If this is the case, it would be considered a failure of randomization. A larger sample would help to address this concern in the future, and ensure the groups are balanced at baseline.

The intervention was based on the theoretical principles of CLT and attempted to balance intrinsic load and extraneous load to accommodate for challenges associated with learning. It is possible that the theory itself is not sufficient to explain all the complexity associated with learning the skill required for PWC driving, or the intervention did not achieve these theoretical aims. Furthermore, the application of errorless learning approaches may not adequately address the reduction in intrinsic and extraneous load. It is necessary to consider the possibility of failure of the theoretical basis for the intervention, or the techniques (errorless learning) used to achieve the theoretical aims.

While fidelity of the intervention was addressed through training and ongoing reporting from the trainers, trainers may not have been able to maintain an errorless learning environment throughout the training. For example, to prevent an error while a learner is driving, the trainer must anticipate the error, and act quickly to prevent it. This can be particularly challenging in tight spaces, where the learner is necessarily close to walls or other installations (e.g., toilets) when they are at risk of a collision. Intervention from the clinician too soon would prevent the learner from having an opportunity to self-correct prior to the error occurring. However, the ability to react in sufficient time when the error does occur in order to prevent it may be very difficult. Furthermore, intervention of any type may be perceived by the learner as an error. Skills of the trainer must be sufficiently honed, in order to maximize the potential for errorless learning in this case. As a result, modifications may be required for the protocol, including training provided to the trainers, in order to ensure it is theoretically sound and can be maintained with fidelity.

While trainers exclusively delivered either the CoPILOT or WSP interventions to reduce the potential of theoretical contamination, all trainers had a general awareness of the objectives of the study, which could have influenced results. It is possible WSP trainers may have unknowingly integrated aspects of errorless learning into their training delivery.

The use of shared control technology may have also led to overreliance on the technology to maintain safety. To maintain masking of evaluators, and to ensure participants in all groups had comparable evaluations, the participants did not complete their evaluations using the shared control technology. As a result, their first experience driving a wheelchair without the perceived safety of a trainer's backup control was during their follow up evaluation. This could have led to

increased anxiety and task refusal. As the primary outcome (PIDA) scores task refusal the same as an inability to complete the task, this may have resulted in lower follow up score for the CoPILOT group.[103] This speaks to the concerns raised in the clinical utility interviews (Chapter 3) about the potential for reliance on the technology, and the need to consider carefully when and how to remove the technology to promote independent driving. This may not be possible within the confines of six sessions for some individuals. An individualized approach to training, where the trainer is able to begin withdrawal once the learner is demonstrating safe and independent skill a majority of the time may be appropriate, and therefore may necessitate flexibility in the number of sessions. Furthermore, the establishment of a procedural approach for withdrawal may be necessary prior to further research.

Furthermore, the challenges of assessing clinical outcomes in a randomized trial with a small heterogenous population are important to consider. Given the heterogeneity of the participants in this study, and the inability to assess the primary outcome at baseline, it is possible the groups varied significantly at baseline on the primary clinical outcome of objective driving skill. This could be addressed by having all participants complete baseline assessments using the CoPILOT system, which would reduce the associated risk. In this case, evaluators would also require training on the safe and appropriate use of the CoPILOT system.

The challenges of assessing clinical outcomes in a randomized trial are further compounded by challenges with self-report in a population with cognitive impairment, which may produce invalid results on subjective tests.[184,185] Future exploration of the use of shared control for older adults with cognitive impairments may be better suited to study designs which

embrace individual experiences and provide opportunities for customization of the intervention, including single subject and small sample designs.

When one looks to the qualitative results to help understand the clinical outcomes, there is a mismatch between the qualitative and quantitative data. Although there was no statistically significant difference between groups, the CoPILOT group appears to have generally scored lower than the WSP group on measures of objective skill. In the absence of data on the minimal clinically important difference for the PIDA, it is difficult to say whether the differences between groups are clinically relevant. The mean scores for all groups fell at or above 75%, which is indicative of an ability to complete the assessment with minor difficulties, with scores averaged across all skills. Therefore, it is possible differences in the group mean are attributable solely to chance and are not clinically relevant. However, the qualitative results suggest there were benefits to the CoPILOT program and the use of shared control, and even areas where the WSP group may have benefitted from the use of shared control. The qualitative data affirms the conceptual rationale of providing learning opportunities through modelling and demonstration, allowing clinicians to provide experiences which reduce stress, and promoting safety for the client, others in the environment, and the clinician. This confirms the benefits and importance of mixed methods research to overcome some of the challenges associated with the use of clinical trials in complex rehabilitation research.[75]

5.4.4 Limitations

This study provided sufficient data to understand the feasibility of study processes, as per the primary study objective, but was not sufficiently powered for clinical outcomes. A future study should address this limitation.

Recruitment was challenged by eligibility criteria, particularly the exclusion of individuals who were not able to speak English well enough to complete the baseline and follow up evaluations. While there are validated versions of both the MoCA[192] and the GDS[193] in Chinese (most commonly reported language affecting eligibility), there are no translated and validated options for relevant clinical outcome for wheelchair use (i.e., PIDA, WST-Q-P, WheelCon, WhOM). Even if validated versions of all study measures were available in other key languages, the study team would require fluency in order to administer the evaluation and training. In multi-cultural environments like Vancouver, not having a study team (especially evaluators) who can operate in multiple languages, and access to validated outcome measures in locally relevant languages may be severely limiting to a clinical trial.

We were unable to complete baseline evaluation for objective wheelchair skills (PIDA and WheelTalk test) due to ethical concerns in asking someone to operate a PWC without training. As a result, we were only able to compare T2 scores for each group without knowing whether the groups were equivalent at baseline. Ideally, the primary outcome would be assessed both at baseline and follow up, with an analysis of covariance used to control for baseline score.[194]

We were unable to address the challenge of skill retention over time, the potential future needs of those who may experience further decline in cognitive ability, and the risk associated with this decline. These limitations should be addressed with a longer period of follow-up for the individuals who are successful in demonstrating skill and obtaining a PWC.

As customary care differs by institution, it was standardized in this study to ensure it is comparable in duration to the CoPILOT treatment, minimizing differences in trainer attention.

Results from the control intervention may not be comparable to that received in all residential care facilities locally or in other jurisdictions, as we learned in Chapter 2 that there is limited standardization to approaches, and few individuals are using an evidence-based approach to training.

Finally, to address limitations associated with reliability of the technology, a higher fidelity prototype of the shared control device would be necessary prior to proceeding with a definitive trial. This would also allow the trial to be conducted across multiple jurisdictions, potentially addressing some of the concerns with recruitment and sample size.

5.4.5 Future Directions

The findings of this study indicate the CoPILOT study is feasible for future research, with adjustments to the study protocol. Specific recommendations for inclusion in a future protocol would be reflection on the type of trial, with consideration for robust single sample research design (e.g., multiple baseline design), or a pre-post trial in which all participants complete objective measures at both baseline and follow up, serving as their own controls. Given no difference was demonstrated between training doses, the protocol may also include only the 6-session dose, in order to decrease resource and participant burden. Finally, reducing the number of outcome measures, and ensuring they have been validated for a cognitively impaired population, would ensure more robust results, and reduce burden on the participants.

5.5 Conclusions

This study is the first to evaluate the use of errorless training techniques and dose required for PWC skills training. There is currently minimal research evidence for PWC skills training in the literature. This study demonstrated that all participants were able to learn the skills

required for PWC use with only minor errors in as few as six training sessions, regardless of the method of instruction. Further evaluation of the CoPILOT training program is required with modifications to the protocol, including but not limited to study design, intervention approach, and outcome measures.

Chapter 6: Discussion, Synthesis, and Future Directions

Powered wheelchairs (PWCs) provide individuals who experience mobility limitations with opportunities to engage and participate in their communities and daily life activities.[12] However, the use of a PWC requires the individual to acquire new skills to become a safe and competent driver.[31] This can be challenged by the presence of a cognitive impairment which affects learning, including dementia, or challenges with short term and working memories often associated with aging. These difficulties learning may result in an individual being denied access to a PWC, and consequently denied access to independent mobility and full participation.

While the evidence supporting the benefits of PWCs has been explored in the literature,[10–12,86] there has not been similar attention paid to how we provide training to these individuals, to ensure we are optimizing their potential for independence. There is little to no research on the content, dose, and training strategies which constitute best practice for training safe and competent drivers. The research contained in the chapters preceding, therefore, outline the efforts I have made in contributing these concepts to the body of knowledge in PWC use. The overall objective of my research has been to apply a systematic approach to understanding our current practices in PWC skills training (Chapter 2), the task demands of PWC use (Chapter 4), and to integrate this new knowledge into a training program which focuses specifically on the learning needs of older adults with cognitive impairments (Chapter 5), facilitated by new technology developed in the course of my research (Chapter 3). In this final chapter, I will discuss overall findings, providing synthesis of the four studies which comprise this dissertation, and note key findings and insights, as well as potential implications of the research. Finally, I

will identify strengths and limitations of the body of work as a whole, and potential future directions for this area of research.

6.1 Multiple Research Approaches and Paradigms in Rehabilitation Research

A range of methodological approaches were used throughout the four studies including semi-structured interviews, an online survey, a think-aloud task analysis, and a mixed methodology feasibility randomized controlled trial. Rather than focus on a single approach, this ensured each objective was investigated with the approach best suited to that area of knowledge generation, and supports the benefit of multiple paradigms in a complex area like rehabilitation research.[75,200] Chapters 2 and 3 relied on a survey and qualitative interviews from a post-positivist perspective, each exploratory qualitative approaches to help develop a more robust understanding of PWC training and the clinical application of shared control. In Chapter 4, a think-aloud approach was applied to a task analysis, combining a research method commonly used in development of interactive technologies[201] with the clinical practice of task analysis.[70] Drawing methodological approaches from multiple paradigms provided an opportunity to ensure the approach is the best suited to the information which is sought.

In contrast, Chapter 5 embraced a mixed-methodology approach to address feasibility of study processes and clinical outcomes. The use of mixed methodology is particularly well suited to a feasibility trial, where we are aiming to understand whether it is worthwhile to pursue a particular research approach.[202,203] Each of the indicators was measured or described using the methodology best suited to that line of inquiry. Furthermore, the inclusion of qualitative data provided context which helped to understand the quantitative results. Mixed methodology can be distinguished by implementation sequence, priority, and level of integration.[75] In this case, we

used concurrent implementation, whereby qualitative and quantitative data were collected throughout the course of the study. Although previous phases of the research gave priority to exploratory methods, priority in this phase of the research was largely explanatory, using the qualitative data to help explain and understand the results obtained from the treatment outcomes. This explanatory priority allows us to consider the possible reasons for the results, and also to identify divergent results between the qualitative and quantitative approaches. Finally, integration was at the level of data collection and interpretation.

Working with a combination of new technologies and a new intervention, the use of mixed methodology provided greater insight into some of the challenges encountered during the trial. While a number of the study processes were feasible, there were substantial challenges in recruitment, treatment adherence, and resource use, including both participant and trainer burden. We also encountered challenges with the lack of valid and reliable outcome measures for the population of older adults with cognitive impairment. The additional qualitative data provided insight into the nature of those challenges. Recruitment, for example, was limited by gatekeeping by clinicians in practice, as well as inclusion and exclusion criteria related to cognition and language. Treatment adherence was limited by factors not associated with the intervention, including participant health and wellness, and the busy environment in long term care. Resource use was higher in groups using the novel technology; qualitative data provided contextual details to inform plans to address this in future trials with the use of a higher fidelity prototype. Finally, qualitative data from our evaluators provided insight into the challenges inherent in the outcome measures used, which inform our understanding of the clinical outcomes for each intervention.

While the feasibility trial provided valuable data, it also called the use of a randomized controlled trial into question for a complex rehabilitation intervention in a heterogeneous population.[204,205] Given the small size of the population overall, it is reasonable to assume some of the feasibility challenges encountered, especially recruitment and the adequacy of outcome measures, would continue to be difficult in a larger trial of a similar nature. There are opportunities to consider future research using alternative methodologies, including single subject designs, which would provide additional flexibility in the delivery of the intervention to tailor it to the individual.[206,207] This type of design could also be integrated into an existing clinical environment more easily, to assess the effectiveness of the training in a clinical setting with the real constraints which are present.

Implications: For future research, an implementation RCT, where the existing care team is trained to provide PWC skills training interventions, may be a more appropriate approach. This requires sustained communication between the study team and the trainers, and buy in from facility managers, occupational therapists, and rehabilitation assistants. Outcome measures which are valid and reliable for the population may also provide greater insight into the differences between interventions.

Overall, the preponderance of methodologies used throughout our research were qualitative approaches. Given this is a relatively new area of inquiry, qualitative approaches are well suited to knowledge generation. Additionally, the complexities of rehabilitation research beg for a more in-depth understanding of feasibility and clinical outcomes of the research, which can be met through the inclusion of qualitative data. Qualitative data helped to understand the

feasibility results, impact of the training experience, and clinical application of the shared control technology and CoPILOT approach.

Implications: Mixed methodology research provided valuable data to evaluate the feasibility of study processes, and to understand the experiences of both trainers and participants in our feasibility trial. In future trials, inclusion of quantitative and qualitative approaches may provide depth to the analysis, while ensuring the client's experience is taken into account.

6.2 Understanding Powered Wheelchair Training

Chapter 2 focused on understanding current PWC training, through the lens of clinicians experienced with clients across a range of populations and settings. This investigation comprised of two studies: a survey to develop a broader understanding of the general practice of clinicians across North America, and in-depth interviews with clinicians in British Columbia to understand common practices in PWC training, tools and techniques used, and barriers and facilitators to providing training. The findings largely demonstrate, despite acknowledgement of the importance of training in the wheelchair provision process by key international organizations including the World Health Organization[88] (WHO) and the Rehabilitation Engineering and Assistive Technology Society of North America[89] (RESNA), local health authorities, and clinicians themselves, that there are environmental barriers to providing training. While both the survey and interview results indicate that clinicians are driven to engage in client-centred practice and provide the necessary training, they are limited by the tools, resources, and professional development they require.

The acknowledgement by most clinicians in our survey that they do not use an evidence-based approach to their training is not surprising – there are few available to them in the literature. While the Wheelchair Skills Program is available online at no cost, the focus of this program is on developing discrete driving skills (e.g., turning 90 degrees, getting over a low threshold) using the principles of motor learning.[43] The challenge with this is two-fold. First, based on the results of the think-aloud task-analysis reported in Chapter 4, we now understand PWC use to be more complex than simply completing discrete skills. A user needs to have a broad awareness of their environment and be capable of developing skills across the spectrum of physical, sensory, and cognitive abilities. Second, motor learning may not be the only or optimal approach to training for all individuals, particularly given the relatively low level of motor skills required to be a competent PWC user.

Implications: Training programs which do not consider cognitive skills, or the complexity of environments may not address the entire spectrum of skills required for safe and competent use.

The challenges inherent in low use of evidence-based approaches for PWC skill training are compounded by the finding there is so little time and funding available in clinical practice that training is often not a priority. Training is often limited to helping a new user understand basic controls and driving skills, without attention paid to how the individual interacts with their environment, or how they will integrate their device into their activities of daily living. The consequence is that current practices may not adequately address the needs of the range of learners clinicians encounter in their environments.

Clinicians may also be limited by the professional education they receive in wheelchair skills, impacting their own competence in providing training. A study completed by Best et al.

addressing the presence of manual wheelchair skills training in entry-to practice occupational therapy and physical therapy programs in Canada concluded that while manual wheelchair skills training is included in some way in most programs, it is largely informal, and not guided by a validated evidence-based program.[195] While similar data is not available for PWC skills training, the wide disparity in the volume of literature on manual and PWC would suggest that clinicians may receive even less training in PWC provision and skills.

Implications: Clinicians require more support to provide client-centred practice in PWC provision in the form of funded time, training tools and resources, and targeted professional development. Client-centred practice in PWC provision would acknowledge the specific learning needs of an individual and provide training approaches suited to their unique needs. Without adequate funding and resources to deliver client-centred practice, clinicians will continue to be unable to meet their obligations to work according to the best practices set forth by the WHO and RESNA.

6.3 Understanding Powered Wheelchair Use

To develop a more comprehensive training program, it was necessary to understand the task demands of PWC use. While we have limited literature which has investigated the relationship between PWC use and cognitive and sensory functions,[47,48] there has been no systematic approach to understanding the skills, abilities, and knowledge used on a regular basis while completing PWC driving tasks. The results of this investigation confirmed what is clinically understood – PWC use is complex and requires specific motor, sensory, and cognitive skills and the integration of these in activities such as learning and applying knowledge,

mobility, communication and interpersonal interactions and relationships. The application of the International Classification of Functioning, Disability, and Health (ICF) provided an internationally recognized and widely understood framework for categorizing task demands.[5] While it has limitations, including challenges distinguishing between activity and participation domains,[196] and does not have a method to classify types of knowledge used, this structure proved to be very useful in understanding the full skills and activities used for driving, and provides a starting point from which we can begin to develop more robust assessment and training programs.

What is perhaps most important in our findings is the recognition of the role cognitive functions play in PWC skills. This highlights the need to focus training programs on a greater range of skills, including higher level executive functions like problem solving and decision making. However, it also raises the question of whether these skills are critical for PWC use, or whether an individual who struggles with these skills is still able to become and succeed as a competent driver in the community, or whether levels of ability might be considered across a spectrum. Certainly there is evidence that individuals with visual neglect and profound cognitive impairment are capable of independent powered mobility.[91,112] This implies the associated sensory (e.g., vision or hearing) and cognitive functions, while important, may not be critical, and accommodations may be possible for those who do not have the full range of skills. However, it is incumbent upon researchers, clinician scientists, and those who provide pre-service or continuing education to ensure clinicians have the training tools necessary to meet the diverse learning needs of their clients.

Implications: While we have a greater understanding of the task demands of PWC use, there continues to be a gap in our understanding of the relative importance each of the identified skills plays in the development of competence with PWC driving. Future research, including the development and evaluation of PWC skill assessment and training programs, should consider the evaluation of these skills, and help to develop an understanding of their importance in developing PWC skill competence.

6.4 Client-Centred Practice in Powered Wheelchair Skills Training

The impetus for the research in this dissertation was a conviction that individuals with a range of cognitive impairment would be capable of learning to drive, if provided with appropriate instruction. The mean score on the primary outcome of objective wheelchair skills met a threshold of 75%, the score assigned to the completion of each task with minor difficulty. This was true regardless of training method and there was no clinically or statistically significant relationship between scores on cognitive testing and objective wheelchair skills testing.

Implications: As all participants experienced mild to moderate cognitive impairment, and the mean scores for objective PWC skills indicate that all participants were able to learn the necessary skills to be independent PWC users with minimal difficulty, the assumption that individuals with cognitive impairment cannot learn the requisite skills may be incorrect and should be reconsidered.

The findings of this research also indicate there was no difference in outcomes for the two doses trialed (6 and 12 sessions). However, qualitative results from some of those who received six sessions suggested they would have benefitted from additional training to improve their confidence and provide opportunities for structured practice. In client-centred practice, the

number of sessions can be determined by the needs of the individual, ensuring all learning needs are met, not solely those associated with discrete skill acquisition. This suggests a certain tension, where clinicians and clients may disagree on the necessary training. While clinicians may consider an individual to be capable of independent driving, the client may not have developed the necessary confidence to use those skills in their daily lives. There are also limitations to the amount of training a clinician may be able to provide in a given environment. Shared decision making, central to client-centred practice, and which allows the clinician and client to address these concerns, may be the best approach.

Implications: Six sessions of training were sufficient to ensure participants learned the technical skills required to drive a PWC, however many participants felt they required additional training. Future research would benefit from training provided within the context of existing clinical relationships, with a flexible approach to the number of sessions required. This would provide additional understanding of the relationship between training time and clinical outcomes. Careful evaluation of study design will be necessary to accommodate this additional flexibility.

While cognition is an important component of PWC use, it is clear people with cognitive impairments are capable of learning the required skills. Although there was no difference between groups based on the training method used, the fact that all participants learned PWC driving skills implies both training methods have merit. Furthermore, we were unable to assess change scores for individuals without capturing a baseline score for objective driving. Individual differences between people may contribute to which training method might be best suited to a particular person and their learning needs. This highlights the importance of client-centred practice, where the approach is individualized and contextualized for the client, and used to

maximize their potential.[2] Clinicians who have the time and resources to truly engage in client centred practice and provide individualized service, which comprised one of the key themes of our findings in Chapter 2, would be able to provide skills training on an individual basis, based on the learning needs of the individual. However, in order to do that, they need to have the correct tools at their disposal.

Evidence-based training programs which offer an alternative to the Wheelchair Skills Program could contribute to the range of tools clinicians have available to them. In the CoPILOT training program, Cognitive Load Theory (CLT) was used as the basis for intervention development, with an attempt to balance the load associated with task demands (intrinsic load) and the challenges posed by the environment (extraneous load), in order to allow permit more energy to be allocated to learning itself (germane load).[65] Errorless Learning techniques were used to balance this load, and promote learning through implicit or procedural memory engagement, rather than explicit or declarative memory. For some clients, particularly those who experience training related anxiety or frustration, or take longer to develop the skills required for safety in the training environment, providing an opportunity for errorless learning as one of the training techniques available could be the difference between succeeding and not succeeding in their training.

Implications: PWC driving is a complex task, which relies on the integration of cognitive, sensory, and motor functions. In the absence of one of these functions, interventions should focus on alternative training techniques to ensure an individual is able to develop and maintain independence. Training programs which have been validated and evaluated are needed to provide evidence-based guidance to clinicians in this area.

6.5 Engaging Stakeholders in Knowledge Generation

Among the considerations in designing the research which is included in this dissertation was the question of who the necessary stakeholders were, and how they should be engaged in the generation of new knowledge around PWC use. As much of the work involved the creation of new tools for clinical use, including a novel technology for the clinical environment, clinicians were obviously a key stakeholder to engage throughout the process. However, as the intended recipients of training, it was important to engage the perspectives of PWC users as well.

Clinicians and PWC users were engaged in each phase of the research in different ways. The focus of Chapter 2 was to develop an understanding clinical practice. Engaging the clinicians as research participants, while having the perspective of a clinician myself, provided opportunities for discussion and depth of analyses which might not otherwise have been possible. While this introduces the risk of bias, this positivist approach to qualitative research fails to acknowledge that the researcher is inherently a part of the research process.[197] We addressed this with the inclusion of an etic perspective from two researchers outside the clinical field, who provided a foil for reflexive discussion and analysis. This was valuable in helping to understand and describe the findings; having both emic and etic perspectives may be considered for future research in clinical practice.

The study conducted in Chapter 3 was also an opportunity to engage future users (clinicians) in designing a novel technological clinical tool through an iterative process. Particularly given the development of novel technology, there are benefits to the use of user-centred design.[73,198,199] Providing opportunities to trial the technology allowed better understanding of the concepts being presented in the interviews, and valuable feedback on the

technological development. This engagement had notable impacts on the CoPILOT shared control tool used in Chapter 5.

In Chapter 4, both clinicians and expert wheelchair users were engaged in developing an understanding of the task demands of PWC use. Using a think-aloud process allowed us to elucidate the implicit knowledge held by these individuals, and to learn from their experiences. Furthermore, the integration of both clinicians and expert PWC users provided a greater range of experiences to draw from and acknowledged the importance of lived experienced.

Implications: Future research in PWC skills training should engage the relevant stakeholders, including clinicians and potential future clients. The engagement of clinicians in the development and implementation of the training will help to ensure the training programs remain clinically relevant and work within the constraints of a busy clinical environment.

6.6 Strengths and Limitations

A primary strength of the dissertation is the generation of new knowledge which helps us to understand PWC use and clinical training practices, providing rationale and evidence to develop future research and clinical resources. We continue to require a better appreciation of the role of cognition and cognitive impairment in PWC use. Furthermore, we require a greater understanding of the approaches used for PWC training and the individual characteristics which would contribute to success with each approach. Recognizing how our training impacts learning for different populations may provide greater access to independence for all individuals, regardless of their functional status.

The Systems Approach[72] to intervention development which guided the development of the CoPILOT training program integrates research evidence, a thorough understanding of the task through task analysis, and previous training programs. Applying this approach ensured the intervention was based in the best available knowledge in the area.

All phases of the study included engagement of clinicians and clients as future users of the technology and the training program, as research participants in the iterative development of the technology, and as participants who were given the opportunity to provide qualitative feedback on their experience with the intervention. This strengthens the findings and ensures they are relevant to those individuals who may use them in the future.

The use of multiple paradigms and methods, including a mixed approach provided greater breadth and depth to the findings, while the use of a feasibility trial allowed us to identify the areas to be addressed prior to proceeding to future clinical research in the area.

However, despite the strengths, there are also limitations to be considered. Each study was reliant on volunteers who participated, and therefore cannot represent the views or experiences of those who chose not to participate.[99] This response bias may be particularly salient when considering the findings of the survey, where individuals who are highly engaged in their practice may have been more likely to respond.

Aside from the survey, the single geographic area represented in the remaining three studies may also introduce bias. This may be important in the context of the feasibility trial, where feasibility of study methods may be more heavily influenced by the physical, cultural, social, and institutional environments where the study is taking place. This should be addressed in future research with multiple sites across jurisdictions.

The risks of self-report data are also inherent throughout this research. In the survey, interviews, and think-aloud, responses may have been influenced by the participants desire for social desirability,[111] or by personal or professional motives, including their desire to effect change. This could have resulted in either the over or under reporting of their clinical practices. Similarly, in the feasibility study, trainer and client qualitative data may have been influenced by these same effects. Furthermore, the use of self-report data for clients with cognitive impairments may not have produced valid and reliable results on several the baseline and clinical outcome measures.

Finally, there are both strengths and limitations to the use of CLT. While the use of a theory provides a sound structure to the development of the intervention, the structure may also result in missing critical elements which should have been addressed, or areas not adequately explained by the theory. For example, the use of motor learning principles may be relevant to the demands of learning joystick use, as this is an inherently motor task, however this was not the focus of the intervention and the theoretical approach, so may not have been adequately considered.

6.7 Future Directions

We have only just begun to understand the role of cognition in PWC use, and the skills which are required as compared to those which may be compensated for. While we now have additional evidence demonstrating individuals with cognitive impairment are capable of developing the skills necessary for driving, further research is required to understand the relationship between cognition and success in PWC use.

A new understanding of the task demands of PWC use, combined with knowledge of challenges inherent in current practice which result in sub-optimal training delivery provides an opportunity to develop new PWC skills training programs which address these components. Development and evaluation of new training programs will add to the clinical tools available to clinicians and their clients.

There were specific concerns with the validation of outcome measures used for individuals with cognitive impairments, particularly those self-report measures which have not been previously validated for this population, including the subjective wheelchair-related outcome measures. For future research to be conducted in this population in the area of PWC skills, it is critical that there be future validation of these measures, or new measures developed which are better suited to the population.

With modifications to the training protocol and the research protocol, future research investigating the effectiveness of the training for individuals with cognitive impairment is warranted. A future trial may focus on objective outcomes which are validated for older adults with cognitive impairments and allow for flexibility in the delivery of the intervention, more aligned with the realities of clinical practice. This would be well suited to a single subject or small sample design, integrated within clinical practice.

The use of the CoPILOT technology and training program has potential applications to other populations. For example, it may be worth considering application to a pediatric population, where there is a need to provide opportunities for exploration which are safe, yet independent, in order to develop the skills to be a safe and competent driver. There may also be applications in brain injury or in stroke, particularly with individuals experiencing neglect who

may struggle with learning until they develop compensatory strategies. Providing a safe environment in which to learn could mean the difference between dependent and independent mobility across a range of populations.

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Appendices

Appendix A Powered Wheelchair Training Survey Questions

Demographic Questions

The following section contains demographic questions which will be used only to describe the study sample. Individual responses will not be disclosed during dissemination of findings.

1. What is your professional role?

Please choose the most relevant professional role.

- ○ Occupational Therapist
- ○ Physical Therapist
- ○ Occupational Therapy Assistant
- ○ Physical Therapy Assistant
- ○ Rehabilitation Assistant
- ○ Assistive Technology Professional (RESNA ATP)
- ○ Seating and Mobility Specialist (RESNA ATP/SMS)
- ○ Other, please specify... _____

2. What is your highest level of education?

Please choose one.

- ○ Some high school
- ○ Secondary School/High School
- ○ Trade College / Diploma/Certificate
- ○ Associate Degree
- ○ Undergraduate Degree (BSc/BA or equivalent)
- ○ Master Degree (Clinical, e.g., MOT/MPT)

- ○ Master Degree (Research, e.g., MSc/MA or equivalent)
- ○ Doctoral Degree (Clinical, e.g., DPT, OTD)
- ○ Doctoral Degree (Research, e.g., PhD, EDD)

3. Where do you currently practice.

Please specify the province, territory, or state in which the majority of your practice currently occurs.

4. What is your current practice setting?

Check all that apply.

- ☐ Community/Home Based Care
- ☐ Extended / residential / long term care
- ☐ Acute care
- ☐ Inpatient Rehabilitation
- ☐ Outpatient clinic
- ☐ Specialized clinic, please specify... _____
- ☐ Other, please specify... _____

5. What is the age range of your clientele?

Check all that apply.

- ☐ 12 years of age and younger
- ☐ 13-19 years of age
- ☐ 20-64 years of age
- ☐ 65-84 years of age
- ☐ 85 years of age and older

6. What is your current area of practice?

(e.g., neurological, musculoskeletal, acquired brain injury, general rehab, pediatrics, orthopedics, etc.)

7. How many years have you been practicing?

8. How many years of experience in powered mobility provision do you have?

Training for Powered Wheelchair Use

The following questions apply to your experiences training clients/patients to use powered wheelchairs. We are interested in understanding any training processes, tools, and techniques you currently use in your practice.

1. Please indicate which, if any, evidence-based wheelchair skills training programs you use in your practice.

Evidence-based wheelchair skills training programs include those which are supported by scientific research findings and documented in peer-reviewed literature. Check all which apply.

- ☐ Wheelchair Skills Training Program (Kirby et al.)
- ☐ Driving to Learn (Nilsson et al.)
- ☐ Other, please specify... _____
- ☐ I do not use any evidence-based training programs in my practice.

2. Which powered wheelchair skills do you typically provide training for?

	Always	Almost Always	Sometimes	Rarely	Never
Powered wheelchair controls (e.g., turning on/off the wheelchair, tilt/recline functions)	○	○	○	○	○
Wheelchair charging and basic maintenance	○	○	○	○	○
Transfers to and from wheelchair	○	○	○	○	○

Basic mobility skills (maneuvering around obstacles, turns, ramps)	○	○	○	○	○
Community mobility skills (e.g., navigating curbs, potholes)	○	○	○	○	○
Driving etiquette (e.g., position in hallways, sidewalks)	○	○	○	○	○
Speed control (e.g., speed selection, proportional control)	○	○	○	○	○
Incorporating powered mobility into activities of daily living (e.g., bathing, grooming, dressing)	○	○	○	○	○
Incorporating powered mobility into instrumental activities of daily living (e.g., cooking, cleaning, shopping)	○	○	○	○	○
Public transportation procedures (e.g., tie downs, public transport)	○	○	○	○	○
Personal transportation procedures (e.g., interface with adapted van)	○	○	○	○	○
Negotiating/navigating the environment (e.g., route planning, problem solving)	○	○	○	○	○
Drive mode awareness and selection	○	○	○	○	○

Trouble shooting wheelchair related problems (e.g., how to disengage the motors, common errors)	○	○	○	○	○
Emergency procedures (e.g., obtaining assistance)	○	○	○	○	○

3. On average, how many sessions do you complete for powered wheelchair skills training for each of the following types of client/patient?

	0-1	2-4	5-7	8-10	11 or more
New powered wheelchair user (no prior wheelchair use)	○	○	○	○	○
New powered wheelchair user (previous manual wheelchair use)	○	○	○	○	○
Experienced powered wheelchair user with new access method (e.g., change to sip/puff from head array)	○	○	○	○	○
Experienced powered wheelchair user with new powered wheelchair configuration (e.g., drive wheel position)	○	○	○	○	○
Experienced powered wheelchair user with a new chair (no other changes)	○	○	○	○	○

4. On average, what is the length of each of your training sessions?

○ Less than 20 minutes

○ 20-40 minutes

○ 41-60 minutes

○ Greater than 60 minutes

5. Please indicate which specific training techniques you use when training for powered wheelchair use.

	Always	Almost Always	Sometimes	Rarely	Never
Verbal cues	○	○	○	○	○
Visual cues	○	○	○	○	○
Trial-and-error	○	○	○	○	○
Demonstration (using the client's joystick)	○	○	○	○	○
Demonstration (using a second wheelchair)	○	○	○	○	○
Hand over hand guidance	○	○	○	○	○
Games	○	○	○	○	○
Obstacle course	○	○	○	○	○
Group/peer-based training	○	○	○	○	○
Environmental modification	○	○	○	○	○
Breaking skills down into steps	○	○	○	○	○
Limiting chair functions (e.g., limited speed, available directions)	○	○	○	○	○
Driving simulator or game	○	○	○	○	○

6. Please describe any additional training techniques you use below:

7. How do you maintain safety for the client/patient, yourself, and others in the environment during the training process?

Check all which apply.

- ☐ Maintain close physical proximity to the client/patient and wheelchair
- ☐ Use of a remote emergency stop system
- ☐ Limit environment where the PWC is used until I am certain the client/patient is ready
- ☐ Adjust programming parameters to modify chair performance, please specify... _____
- ☐ Other, please specify... _____

8. Are there any technologies or techniques, which you do not have, which would help you maintain safety for the client/patient, yourself, or others in the environment during the training process?

9. What strategies do you use when training a client/patient who has a cognitive or memory impairment which might influence learning?

- ☐ Increase training opportunities
- ☐ Alter the length of the training sessions
- ☐ Alter the environment in which I train the client/patient
- ☐ Alter my training techniques in other ways, please describe... _____
- ☐ I do not provide training for powered wheelchair use if the individual has a cognitive or memory impairment.

10. What additional information regarding your experience(s) training clients/patients for powered wheelchair use do you feel would help us to understand current practices in this area?

Appendix B Semi-Structured Interview Guides

Interview 1 Guide

Thank you for participating in our study. Today we would like to talk with you about your experiences with assistive technology, wheelchairs, and clients with cognitive impairments, and start to talk about the technology we are working on.

1. Please describe the client population you work with.
    a. Prompt: What range of physical abilities do the clients you work with have?
    b. Prompt: What range of cognitive abilities do the clients you work with have?

2. Please describe the setting in which you work?
    a. Prompt: Describe the setting physically.
    b. Prompt: Describe the typical resident/client.

3. What kinds of assistive technologies do you prescribe for your clients?
    a. Prompt: What type of mobility devices do you prescribe?
    b. Prompt: What other types of assistive technologies do you prescribe?

4. Describe your experience working with individuals with cognitive impairment.

5. Describe your experience completing assessments and training for assistive technologies with individuals with cognitive impairment.
    a. Prompt: How does your assessment process differ with individuals with cognitive impairment?
    b. Prompt: How does your training process differ with individuals with cognitive impairment?

6. Please describe your training and experience working with powered mobility prescription and training.

7. Please describe the process you use for powered wheelchair assessment and training.
    a. Prompt: Do you have a specific process that you follow?
    b. Prompt: How does your process differ with different clients?

8. What are the skills and abilities you are looking for when training and assessing a client for powered wheelchair use?
    a. Prompt: What do you find clients have the most difficulty with?

9. Based on your experience, how does your powered wheelchair training currently differ with individuals with cognitive impairment?
    a. Prompt: How do you ensure clients are safe in the assessment and training process?
    b. Prompt: What types of teaching techniques do you use?
    c. Prompt: What, if any, functions of the wheelchair do you change?

10. What do you think would improve powered wheelchair assessment and training for individuals with cognitive impairment?
    a. Prompt: What factors make it easier for clients during training and assessment for a powered wheelchair?

We are in the process of developing a tool that will give clinicians more control over a wheelchair when training. It would be a remote-control tool that would essentially allow the clinician to override the wheelchair controls to provide guidance or prevent an unsafe situation. Unlike an attendant control, the client would keep control through their joystick, except at the moments you intervene. Once you stop intervening, control would immediately be returned to the client. We'd like to incorporate features that you think might be useful.

11. What do you think about a technology that would allow you to remotely override the client when necessary?
    a. Prompt: How could you use it in your clinical practice?
    b. Prompt: How would it impact the way you complete powered wheelchair assessments?
    c. Prompt: How would it impact the way you conduct powered wheelchair training?
    d. Prompt: What questions do you have about how this technology would work?

12. If you were designing this device, what would you like it to be able to do?
    a. Prompt: No idea is too extreme– we want all your ideas at this point
    b. Prompt: What information would you like it to give you about what the client is doing?
    c. Prompt: What types of things would you like to control remotely?
    d. Prompt: How would you like it to look?
    e. Prompt: How would you like it to feel in your hands?

13. What would a simple and effective remote-control device look like that would best suit your needs? (pencil and paper, clay)
    a. Prompt: Please think aloud as you draw
    b. Prompt: Add physical characteristics like buttons, joystick, touchscreen, size, weight

To help you picture this, we have developed a case-study of the individual you are working with as a clinician. (See Persona Description at end of document)

14. Based on this client, how would you use CoPILOT when you were assessing and training her for powered wheelchair use?

Participant Experience and Interview 2 Guide

Participants will be reminded of the case study they 'met' in Interview 1 (see Case Study). Participants will be shown the existing shared control wheelchair and interface and provided with a demonstration on its use. They will then have the opportunity to both drive the chair as the client (keeping the case study persona in mind), and to act as the training clinician.

1. What are your immediate impressions of the CoPILOT remote control system?

2. Which features did you like the most? Why?

3. Which features did you like the least? Why?

4. There was a visual display on the back of the wheelchair providing information about the input from the client, yourself and output from the chair. What did you think of the visual display?

5. Did you use the data on the visual display when you were operating the chair? If so, how?

6. Can you tell me your general thoughts about the use of the CoPILOT technology when working with your clients?
    a. Prompt: How would or would it not be useful to you as a clinician?
    b. Prompt: How would or would it not be useful to your clients?

7. If you had access to CoPILOT, how might the technology I've shown you today impact your current assessment and training practices?
    a. Prompt: What are the potential positive/negative aspects of using a remote control?

8. Considering the client you were 'training' in this experience (refer to case study), how do you think this technology might work with that client?

The technology you tried was developed for research purposes and provided information on a visual display about the driver and the assistance that you were providing with the remote. Since it was designed for research purposes, it might not meet the needs of powered mobility trainers and assessors. We are now trying to make a remote control and visual display that will work best for powered mobility trainers and assessors.

9. Now that you've had an opportunity to try the basic system, what would a simple and effective remote-control device look like that would best suit your needs? (pencil and paper, clay)
    a. Prompt: Please think aloud as you draw
    b. Prompt: Add physical characteristics like buttons, joystick, touchscreen, size, weight

10. The training system could potentially provide you with a lot of information about how the user is interacting with the wheelchair, and the movements of the wheelchair. What kind of information would be useful for you to have?
    a. Prompt: Some examples could include wheelchair speed, stability/smoothness of wheelchair input, direction of joystick throw, direction of remote-control input.

11. What kind of information would help you as a clinician to supplement your training or assessment decision making?
    a. Prompt: Examples could be tracking control input to determine input smoothness, speed control, smoothness of turns.
    b. Prompt: What other things would be useful to know?

12. What would you like the visual display of that information to look like?

a. Prompt: How would you present the information on the visual display?
b. Prompt: What is the best position for the visual display?
c. Prompt: How should the display and your remote-control device work together?
d. Prompt: What would the optimal size for the display be?
e. Prompt: How could the information be presented in a way that is clear and easy to understand?
f. Prompt: Please sketch the ideal visual display, thinking aloud as you sketch.

13. What other thoughts you would like to share with us about your experience with the technology, or what an ideal display and interface would look like?

Persona Description

Mrs. Chan is an 83-year-old woman who lives at a Lower Mainland residential care facility. She is an active participant in many of the day-to-day activities at the home and enjoys singing and daily exercise classes.
Mrs. Chan has severe osteoarthritis that affects her knees and shoulders and propelling her manual wheelchair has become nearly impossible for her. You have also noticed that she seems to be slowing cognitively, and her short-term memory is impaired. She has trouble remembering multiple step directions, and sometimes does not notice things going on around her.
As the Occupational or Physical Therapist at the home, you would like to consider powered mobility for her. You feel that a powered wheelchair would give her some independence, and allow her to visit independently with her friends, and get around without significant assistance. Six months ago, you offered Mrs. Chan the opportunity to trial a powered wheelchair, but she had difficulty learning the skills needed to operate the chair. She would panic going through doorways and tended to propel the wheelchair forward if she accidentally came in contact with something rather than pulling the joystick back.

Follow-Up Experience and Interview Guide 3
Participants will be shown the most recent shared control wheelchair and interface and provided with a demonstration on its use. They will then have the opportunity to both drive the chair as the client and to act as the training clinician. In the moment feedback will be collected as they use the device. Four modes will be trialed (based on location of kill switch and proportional vs. directional priority).

1. Please tell me your initial impression of the new remote-controlled interface.

2. Please identify the features which you like about the new interface.

3. What changes would improve the function for your use?

4. What changes would you make to the visual interface to enhance the information you are receiving?

5. Consider the modes you attempted. Did you have a preference for the prioritizing proportional or directional control? Why?
6. Did you have a preference for how to activate the second mode - either the large or small trigger? Why?
7. Please provide any additional feedback we haven't discussed yet.

Appendix C Qualitative Themes and Subthemes

Theme	Subthemes
Chapter 2: Current Practices in PWC Skill Training	
Client-centred practice minus resources = gatekeeping	
Trading training practices for safety	
Chapter 3: Clinical Utility of a Shared Control Remote for PWC Skills Training	
A big enabler	Reduce training associated risk Enable alternative training and assessment approaches Necessary clinician training and practice
Changing the Learner Experience	Reduce training-related anxiety, stress, and frustration Building confidence through success Changing the training relationship Mitigating drawbacks to shared control
Focus on the Client, Not on the Device	Intuitive to use As simple as possible
Chapter 5: Perceived Benefit of the CoPILOT Training Program	
See possibilities driving	
More complicated than driving a bicycle	

Appendix D Prototype Remote Controls and Features

Prototype 1 (Interview 2)	Features
	• Two-handed control • Connect to wheelchair control (A) • Override with proportional control by depressing trigger (B) and moving joystick (C) simultaneously • Emergency stop (D) • Release emergency stop (E)
Prototype 2 (Interview 3)	**Features**
	• One-handed control • Connect to wheelchair control (F) • Proportional or direction-only mode selection (G) • Override wheelchair in selected mode (H) • Emergency stop (I) • Release emergency stop (J) • Increase/decrease speed by 25% (K) • Record system error (L)

Appendix E Guided Task Analysis Instructions and Template

1) Explain the concept of Task Analysis to the participant, and present an example of the steps which might be chosen;

2) Explain that for each skill, you will ask the participant to develop a list of 7-10 steps which must be completed for the skill to be successful

3) For each skill: Show the participant the video of themselves completing the specific skill.

4) Ask the participant to identify how the skill was completed, in a series of 7-10 steps.

Potential prompts:	If you were teaching someone how to do this, what would you tell them to do?
	What did you have to physically do?
	Which parts of the wheelchair did you interact with?
	What things were you looking or listening for?

5) Once the participant has negotiated the 7-10 steps they feel represent the task, ask the participant to consider the knowledge, skills, and abilities required to complete it (the interviewer should help put the items the individual identifies in the correct columns).

Potential prompts:	What knowledge did you use? Consider knowledge of the skill, the environment you were doing it in, or knowledge about your own abilities.
	What skills did you require? Skills are things which can be learned and might include specific movements or actions. (Refer to the List of Motor and Process Skills)
	What abilities did you need? Abilities are things your body or brain are able to do – they could include things like reaction time, vision, strength, or flexibility.

6) Ask the participant to identify tips or tricks for learning that particular skill.

Task: _____

Step	Knowledge	Skills	Abilities
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Appendix F CoPILOT Training Manual

Collaborative Power mobility Innovative Learning OpporTunity

Trainer Manual

CoPILOT Intervention

Introduction

Welcome to the CoPILOT Intervention Training Manual for the CoPILOT Study. As a trainer for this intervention, you will be responsible for delivering the CoPILOT Intervention, using the CoPILOT Remote Control System and the training principles outlined in this manual.

The following document will guide you through the research protocol requirements, as well as the training principles and techniques required to implement the CoPILOT training program.

Contact Information

If you encounter any difficulties during your training period, or have any questions please send an email to:

Emma Smith

OR

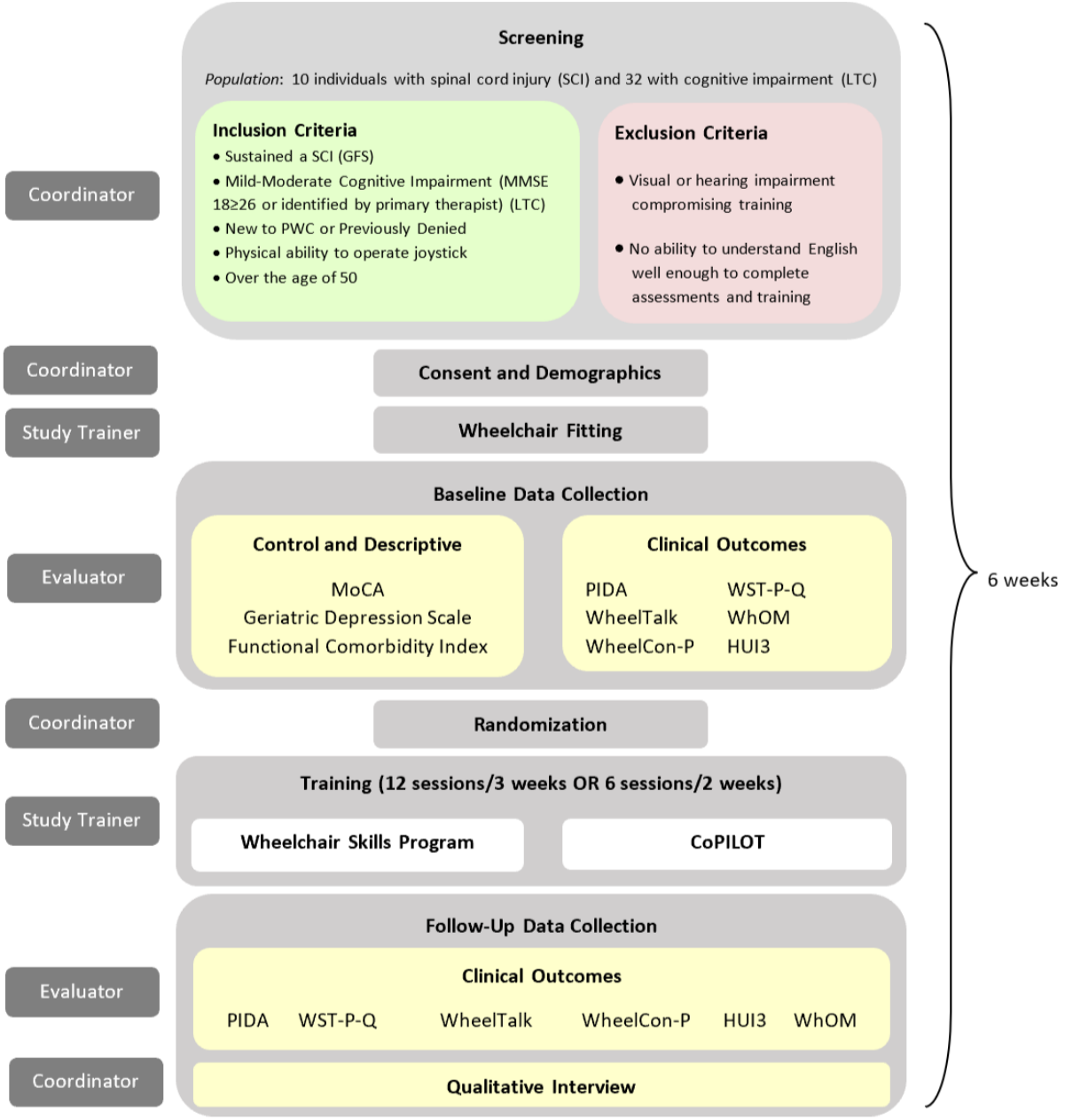
Erica Digby

If you have a situation which requires a more immediate response (see Emergency Procedures section), please contact as soon as possible:

Emma Smith OR

Erica Digby

Overview of the CoPILOT Study



Prior to Training

Documentation

Prior to the first training session, trainers will be provided with copies of the following documentation and results of the participant's baseline evaluation:

a) Chart Summary (Appendix A): Includes information about the participant's condition, transfer status, and any relevant information regarding the participant's training needs.
b) Wheelchair Fitting Form (Appendix B): This is provided for the trainer's awareness and may be used to record any changes which are made to the user's seating position during the training program.
c) MoCA Assessment Score Report (Appendix C)
d) Wheelchair Skills Test Summary Report (Appendix D)

Scheduling

When the trainer is assigned to a participant, the research coordinator will work with the trainer and participant to identify a minimum of one week (four sessions) of training times. During the first training session, the trainer may work collaboratively with the client to identify additional training times for the second and third week. Trainers should expect to begin 15 minutes prior to the scheduled training time for equipment set up, and plan for an additional 15 minutes at the end if required to complete documentation or wrap-up.

Consent Monitoring

Participants in this study may be experiencing conditions which impact their ability to consent to treatment. For individuals who are unable to consent, we will be using a process of legal consent from the substitute decision maker, and a process of assent by the participant.

Due to potential challenges with memory loss, we will also be using ongoing consent monitoring to ensure participants continue to consent to treatment. Therefore, as with any clinical intervention, trainers should obtain verbal consent from the participant at the outset of each training session and monitor the participant throughout for any verbal or physical (body language) signs that they no longer wish to consent. These should be recorded by the trainer for discussion with the team in the Wheelchair Skills Training Log (Appendix E) following each session.

Training

Overview

- Participants allocated to the CoPILOT Intervention will receive the study intervention protocol from a CoPILOT study therapist four times per week for a total of 3 weeks, or three times per week for a total of 2 weeks.
- Participants will receive all other rehabilitation treatments available to them at the facility where they are residing. This will not be monitored.
- Prior to starting training, participants will complete baseline assessments with a study evaluator and be fitted for a powered wheelchair by a study therapist or study coordinator.
- Following the study, participants will be re-assessed by a study evaluator. It is very important the assessor does not know which group the participant was assigned to. Trainers and participants must not disclose this information at any time when the evaluators may be present.
- To maintain the integrity of the study, please do not share with others the protocol your participant has been assigned to. At the completion of the study, the results will be formally disseminated.

Training Schedule

Each participant will receive 6 or 12 training sessions, at a maximum of one hour per session. Training sessions should occur four times per week for three weeks. Sessions missed should be made up within the week if possible or recorded if not possible on the Study Trainer Follow-Up Report (Appendix F).

Training Location

All training will take place at GF Strong Rehabilitation Centre or the participant's long-term care facility. Trainers will meet the participant in a location of the participant's choice, taking into account transfer needs into the powered wheelchair. Training should take place in environments the participant is likely to use (bedroom, hallways, meal hall). These environments should be as close to natural as possible.

Training Principles

Errorless Approach: Tasks should be taught and practiced using an errorless approach which begins with error-free demonstration of the task by the trainer, using the CoPILOT remove control in proportional mode. The progression of training should follow the principles of increasing error and increasing effort over time. This progression and specific training techniques can be found in Appendix H.

Real Environment: Wherever possible, training should be completed in the same environment where the task will be used in the participant's daily life. Where the real environment may be overwhelming or anxiety producing, the trainer should attempt to find a similar environment which is less overwhelming, rather than a simulated environment.

Whole Task Learning: Whenever possible, tasks should be completed in their entirety. The participant is not required to complete the entire task independently and may receive assistance for all or part of the task. During periods of assistance, the CoPILOT remote control should be placed in Direction Only mode to allow the participant to have control over their own speed. Tasks should be broken down into steps to complete training (see guides for component skills).
Skill Focus: Within the context of whole tasks, the trainer may choose to focus on specific skills (e.g., speed control, navigating the social environment). In this case, the trainer should complete all parts of the task which are not the area of focus and allow the participant to focus on one specific aspect of task completion.

Training Session Structure

Each session should be task oriented, according to the participant's goals, and adhere to the same general guidelines:

1) Review previously learned tasks (if applicable), providing assistance as necessary
2) Demonstrate, explain, and practice new tasks to be learned using the skill progression outlined in Appendix H.
3) Review tasks practiced in the session

Demonstrate skills to be practiced in the subsequent session.

Component Skills:

Each task may be made up of a combination of the following component skills. The steps required to complete each of these skills are outlined in the task analyses in Appendix B. These steps may be used to provide verbal prompts, and to break tasks down to provide assistance in whole task learning.

1) Driving forward and stopping
2) Turns to the right and left driving forward
3) Turns to the right and left driving backwards
4) Negotiating a crowded space

There are also three specific tasks which are broken down in the task analysis in Appendix B. These have specific characteristics which may differ from those listed above. These tasks are also broken down into steps which can be used to promote learning through error-minimized methods.

5) Navigating an elevator (principles may be applied to other tight spaces, including bathrooms)
6) Driving through a hinged doorway (may also be applied to doorways without hinged doors with minor modifications)
7) Parking at a table

Training Session Content

Content of the training sessions will depend on the participant's capabilities and learning progress. The following is a general overview of a potential training schedule, which may be modified according to the participant's needs:

Session 1: Introduction and orientation to the wheelchair and controllers, initiating movement, stopping the wheelchair.

Session 2: Review introduction and orientation, introduce speed control (proportionality) while driving in a straight line, planned and emergency stops.

Session 3: Review orientation, planned and emergency stops, continue practice of speed control, introduce directional control.

Session 4: Review orientation, planned and emergency stopped, continue practice of speed control and directional control.

Session 5: Review planned, and emergency stops, continue practice of speed control and directional control, introduce discreet movement and path planning.

Session 6: Review stops, continue practice of speed and directional control, practice path planning.

Session 7: Review stops, practice whole task path planning with speed and directional control, introduce 90 and 180 degree turns.

Session 8: Review turns and whole task path planning, begin to reduce reliance on assistance for speed and directional control.

Sessions 9-12: Complete whole task practice for most commonly completed tasks in the participant's daily life, reducing assistance for speed and direction control gradually.

Spotting and Maintaining Safety

CoPILOT Trainers have access to the CoPILOT remote to promote safety throughout the training process. There are multiple options to promote safety when there may be an imminent risk for the wheelchair user, trainer, or others in the environment. Some combination of options may be used to promote safety during the training process.

1) Remote emergency stop protocol: The CoPILOT remote provides an opportunity to stop the wheelchair from up to 30 feet away. In the event this is required, the trainer may press the large trigger button to stop the chair. When this trigger is activated, the user's joystick will no longer provide input to the chair, until reactivated. See Appendix C for a diagram.
2) On-Chair Emergency stop protocol: Each of the CoPILOT chairs is outfitted with a red emergency stop button which may be activated if the remote emergency stop protocol is not operational. This will shut interrupt communication between the joystick and the wheelchair motors, causing the chair to stop. To reactivate the chair, you must turn the chair off and on again via the OMNI system.
3) Chair power emergency stop: As with any other powered wheelchair, the power to the chair may be turned off through the use of the on-chair power button. The trainer must be in close proximity to the chair to activate this protocol.
4) Direction Change: In the event of a potential collision, the trainer may activate the directional control of the CoPILOT remote to avoid the collision by making contact with the joystick on the remote and navigating away from the collision.

5) Speed Control: In the event of a potential collision, trainers may alternately choose to slow down the wheelchair in 25% increments until the chair is stopped, or the chair has slowed to a manageable speed.

All participants should wear safety belts during training, to ensure they remain in the chair in the event of an unexpected bump or collision. Trainers should maintain awareness of the participant's capabilities and may increase distance between the user and the trainer as competence increases.

Documentation of Training

Following each training session, the trainer is requested to fill out the Wheelchair Skills Training Log (Appendix F) on the study tablet or at home using the Qualtrics link (below).

Following the completion of all training sessions for the participant, the trainer is requested to fill out the Study Trainer Follow-Up Report (Appendix F) on the study tablet or at home using the Qualtrics link:

https://ubc.ca1.qualtrics.com/jfe/form/SV_6orl6DmcJe3VvSJ

To log into the survey, open a browser on the tablet provided for training documentation and use the links above. You must be in a Wi-Fi enabled zone to access the links. Alternately you may complete these from home on your own device using the links above.

Emergency Procedures and Adverse Events

In the event of an emergency, your first responsibility is to ensure the participant is safe. The following procedures should be followed in the event of an emergency.

Participant Illness: In the event the participant becomes ill during the training session, or reports feeling unwell, offer the participant the opportunity to conclude the training session and return to their room. Notify the nursing station in the participant's unit on your return, complete an Adverse Event form (Appendix G) and record this information in the daily training log.

Participant Fall: If a participant sustains a fall while attempting any wheelchair skill or transfer, as the participant not to move until an assessment can be completed. Obtain assistance from a staff person to complete an assessment and, if possible, return the participant to their chair. Offer the participant the opportunity to conclude the training session and return to their room. Notify the nursing station in the participant's unit on your return, complete an Adverse Event form (Appendix G) and record this information in the daily training log.

Autonomic Dysreflexia: Autonomic dysreflexia is a condition where there is a sudden onset of high blood pressure. It is most common in individuals with T6 or higher spinal cord injury. This is a potentially life-threatening condition. Observe the participant for the following symptoms while completing training:

- Intense headache
- Profuse sweating
- Flushed face
- Goosebumps

- Apprehension
- Blurred vision

If you notice a sudden onset of these symptoms, or they are reported to you by the participant, ensure the participant is in an upright position, there are no kinks in the catheter (if applicable), and obtain assistance from facility staff to assess the participant. Notify the nursing station in the participant's unit on your return, complete an Adverse Event form (Appendix G) and record this information in the daily training log.

If the participant is in significant distress, or becomes non-responsive, follow procedures for Code Blue below.

Code Blue: Cardiac or Respiratory Distress, Non-responsive Participant: In the event of significant cardiac or respiratory distress, or a non-responsive participant, we will follow facility specified Code Blue procedures as follows:

1) Dial "333" from any telephone at GF Strong to reach the front receptionist and report a "CODE BLUE" and your location (e.g., Basement, Wheelchair Skills Room; First Floor, Gym);
2) Repeat to the front receptionist
3) Ask the receptionist to repeat
4) Administer First Aid if you are qualified until help arrives

CODE RED: Fire or Fire Alarm*:* We are required to follow established Fire procedures while working at GF Strong:

If the Fire is in your area:

1) Ensure anyone in the area is safe
2) Pull the fire alarm
3) Dial 9-911 from any GFS phone and tell the operator there is a fire at GF Strong in your location (describe location including floor of building). The address is 4255 Laurel St.
4) Evacuate or extinguish if safe to do so

If the fire bell rings:

1) Listen to the PA announcement and follow instructions.
2) If the fire is in your area, remove the participant to a safe area or outside.
3) If the fire is not in your area, remain with the participant and close all doors until it is over.
4) Follow evacuation instructions as provided on the PA system.

Additional Resources

The CoPILOT Technical Manual Outlines the steps required to start and operate the CoPILOT device, as well as additional troubleshooting tips and FAQs.

Chart Summary

Participant ID: _____ Date of Initial Chart Review: _____

Diagnosis:

Date of Onset or Injury:

Current functional status (including mobility):

Cognition Status (including capacity to consent to treatment):

Transfer status

Date	Status

Additional Notes as Required

_____

_____

_____

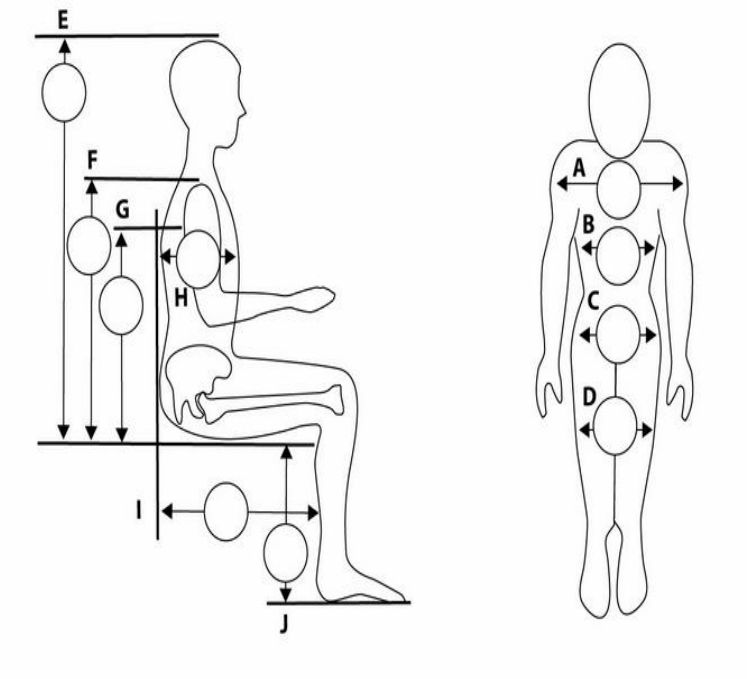
_____

_____

_____

Wheelchair Fitting Form

Participant ID: _____ Rater: _____ Date: _____



Measurements

A. Width of Shoulders _____in
B. Width of back _____in
C. Hip width _____in
D. Knee width _____in
E. Height to top of head _____in
F. Height to shoulder _____in
G. Height to Axilla _____in
H. Depth of torso _____in
I. Upper leg length _____in
J. Lower leg length _____in

Range of Motion

1. Hip range _____◦
2. Knee range _____◦
3. Ankle range _____◦
4. Neck range _____◦

Postural Tendencies

1. Scoliosis
    a. Present Y/N
        i. Convex to R/L
2. Kyphosis
    a. Present Y/N
        i. Fixed/Flexible
        ii. Level
3. Lordosis
    a. Present Y/N
        i. Fixed/Flexible
        ii. Level
4. Hip Rotation
    a. Present Y/N
        i. Hip Forward R/L
        ii. Fixed/Flexible
5. Trunk Rotation
    a. Present Y/N
        i. Shoulder Forward R/L
        ii. Fixed/Flexible
6. Obliquity
    a. Present Y/N
        i. Hip high R/L
        ii. Fixed/Flexible

Notes:

_____

_____

_____

MoCA Assessment Report

Image of participant worksheet

Specific Scores

Item	Score	Item	Score
Attention: Forward digit span	/1	Abstraction	/2
Attention: Backward digit span	/1	Delayed Recall	/5
Serial 7 Subtraction	/3	Orientation	/6
Language: Repetition	/2		
Language: Fluency	/1		

Comments/Expected Impact on Training:

Wheelchair Skills Assessment Summary

Power Mobility Indoor Driving Assessment

Item	Applicable	Score	Comment
Bedroom			
1. Accessing bed- right			
2. Accessing bed – left			
3. Approaching dresser			
4. Approaching closet			
Bathroom			
5. Into bathroom			
6. Approaching sink			
7. Approaching Toilet			
8. Exit bathroom			
Doors			
9. Sliding doors – mat trigger			
10. Swing Open Doors – mat trigger			
11. Automatic doors – button trigger			
12. Regular doors			
Elevators			
13. Entering elevator			
14. Spacing in elevator			
15. Exiting elevator			
Parking			
16. Parking under table			
17. Parking beside table			
18. Back-in parking			
19. Parallel parking			
Ramps			
20. Up a ramp			
21. Down a ramp			
Skilled Driving			
22. Turning Right			
23. Turning left			
24. 180°Turn			
25. Driving backwards			
26. Manipulating – congested area			
27. Maneuverability			
28. Obstacles – unexpected			
29. Speed selection*			
30. Sharing public space*			

Wheelchair Skills Program Questionnaire Summary

Total Score for Capacity: /60

Skills participant feels capable of performing (Score of 2)
Skills participant feels capable of performing, but not as well as they would like (Score of 1)
Skills participant has never done, or cannot do (Score of 0)
Notes/Comments:

WheelTalk Summary

	Baseline	Dual-Task
Time (seconds)		
Number of pylons hit		
Number of letters recited		
Number of errors		

WhOM Summary

Participation Goals	Importance	Satisfaction

Wheelchair Skills Training Log

Participant Number: _____ Trainer: _____

Date		Start time		End time	

Skills trained	
Safety Concerns	
Equipment Issues	
Plan	
Notes and Consent Monitoring	

Trainer Follow-Up Report

Participant Number		Trainer Name	
Training Start Date		Training End Date	

How many training sessions were completed?	
If less than 6 or 12, please provide an explanation for missed sessions:	
Please describe any challenges you faced adhering to the research protocol:	
Based on this participant, are there any protocol changes which are required prior to proceeding with the next participant?	
Please provide any other comments or issues which you would like to discuss with the team at the next meeting for inclusion on the agenda	

Adverse Event Reporting Form

Participant Number:	**Date of Adverse Event:**
Description of Event:	
Severity 1 = Mild (no training missed; able to continue participation in study) 2 = Moderate (will need to miss 1-4 training sessions; still in study) 3 = Severe (hospitalization/medical intervention required / withdrawal from CoPILOT study)	**Relationship to Intervention** 1 = Definitely related 2 = Possibly related 3 = Not related
Outcome of Adverse Event:	

Signature:	**Name/Title:**	**Date:**

Notified: ○ **CoPILOT Coordinator** ○ **CoPILOT PI**	**Name:**	**Signature:**	**Date:**

Comments:

Specific Skill Task Analyses

The following seven pages outline the steps required to complete seven wheelchair tasks. The first four are tasks which are often used together or in sequence. Collectively, these tasks make up the majority of the powered wheelchair "driving" in an environment.

1) Driving forward and stopping
2) Turns while moving forward
3) Turns while moving backwards
4) Navigating a congested area

The next three are tasks which are often used and have very specific task requirements outside of the typical driving behaviours. In some cases, a task may be representative of multiple tasks (e.g., many of the maneuvers required for these three tasks collectively apply in a bathroom).

5) Navigating an elevator
6) Getting through a hinged door
7) Parking at a table

Each task is broken down into individual steps, which are separated into boxes.

Boxes with rounded corners indicate the start or end of the task.

Boxes with hard corners indicate the steps of the task.

Diamond shaped boxes indicate a decision point, where there may be more than one option for completion of the task.

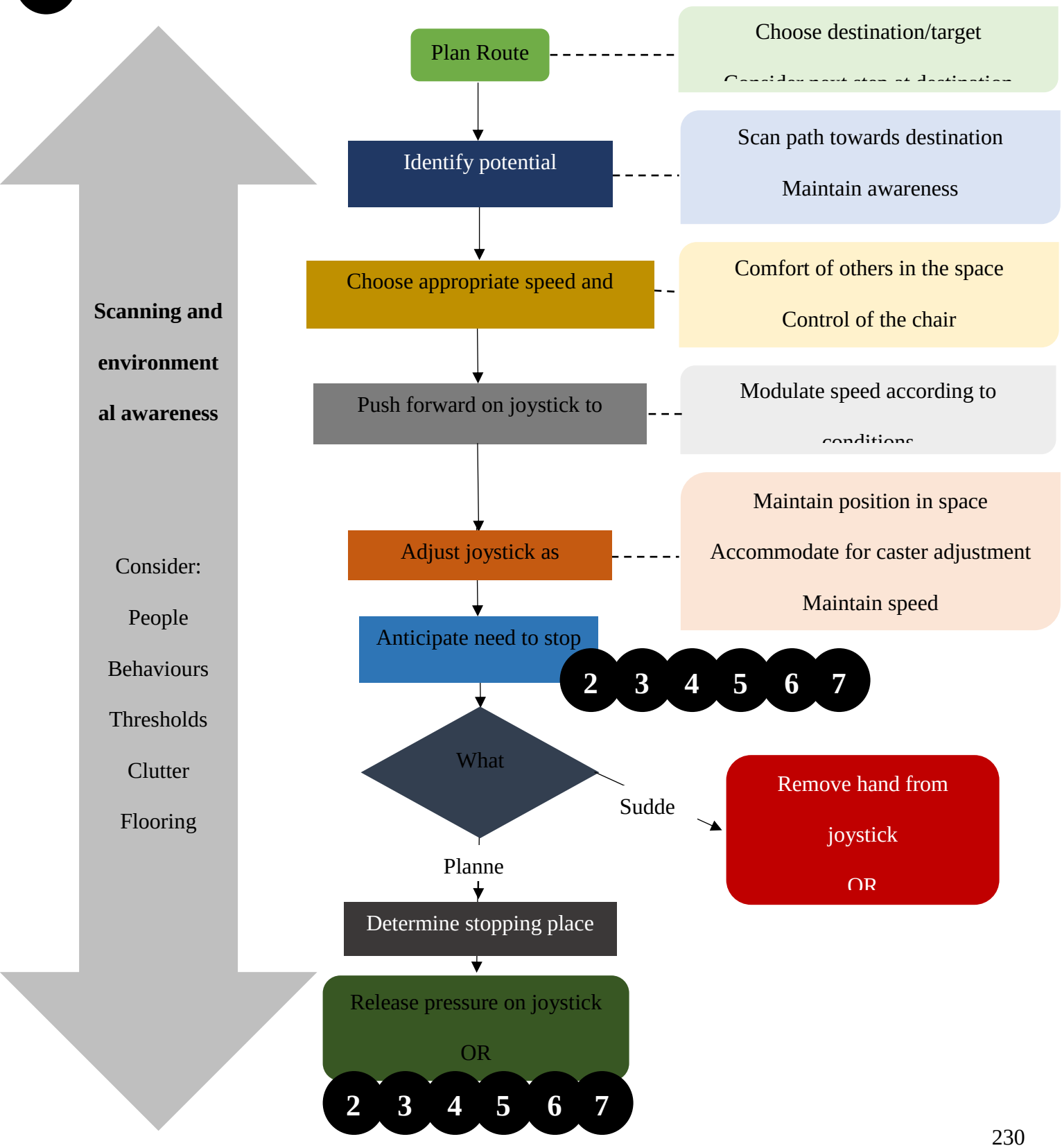
To the right of each step, you will find additional notes or cues which may be provided to the wheelchair user which help to provide context, information, or questions related to completion of that step.

At the top of each page, each task is noted with a number in a black circle. These circles are also used throughout the tasks to indicate where tasks may intersect, or where one task may follow completion of another.

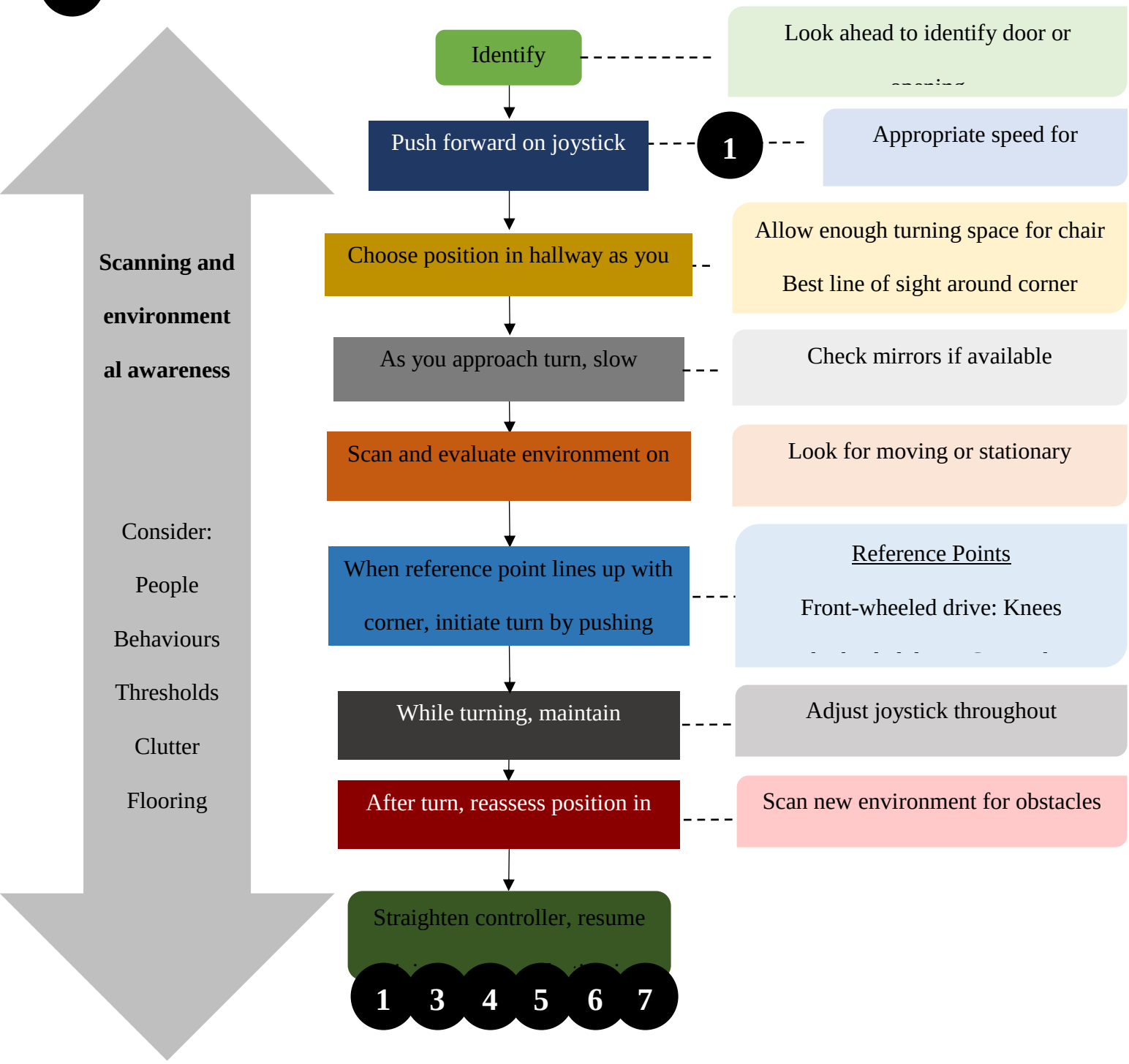
1

Throughout, you will note a continuous focus (on the left-hand side) on environmental scanning and

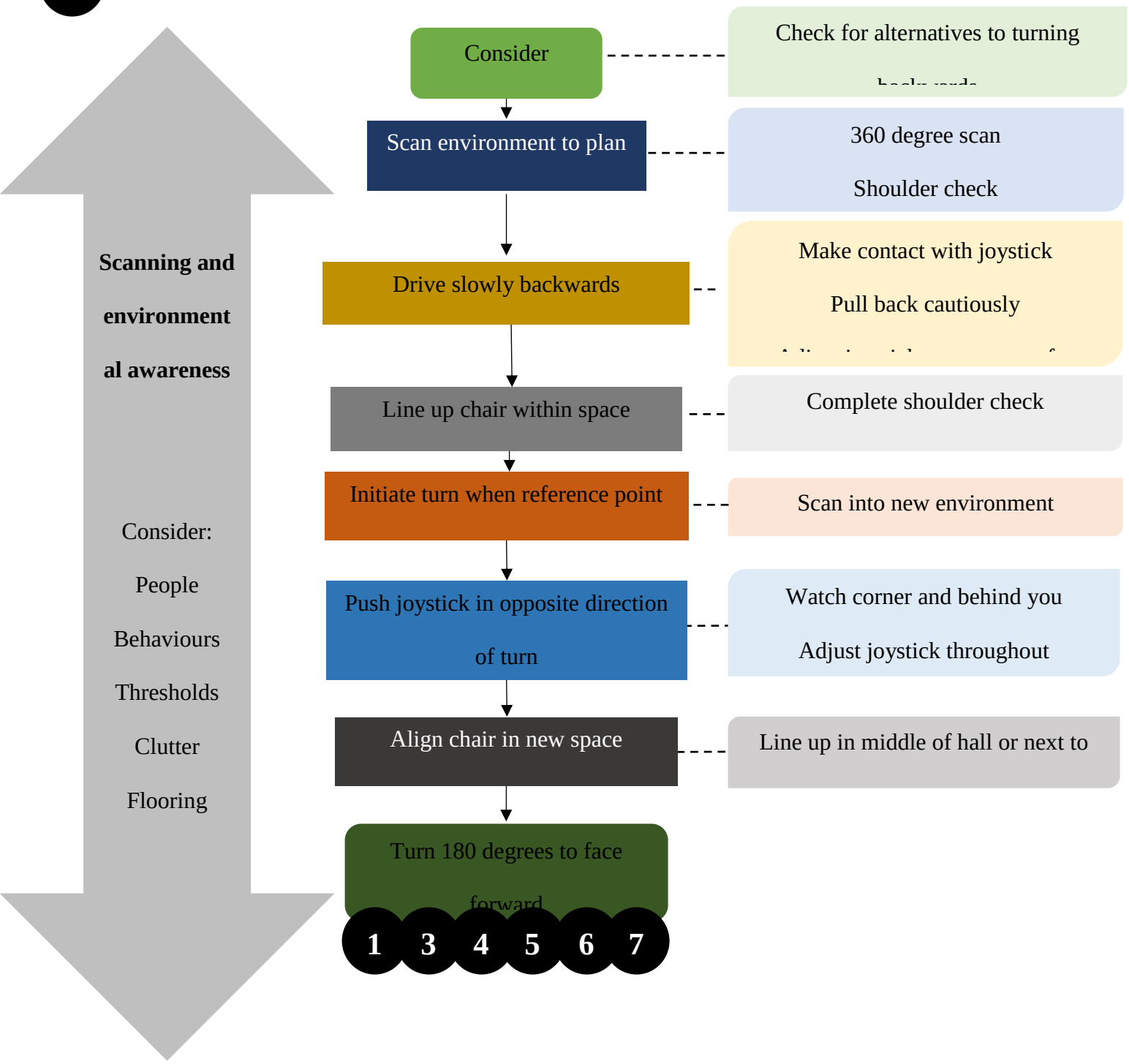
Driving Straight and Stopping

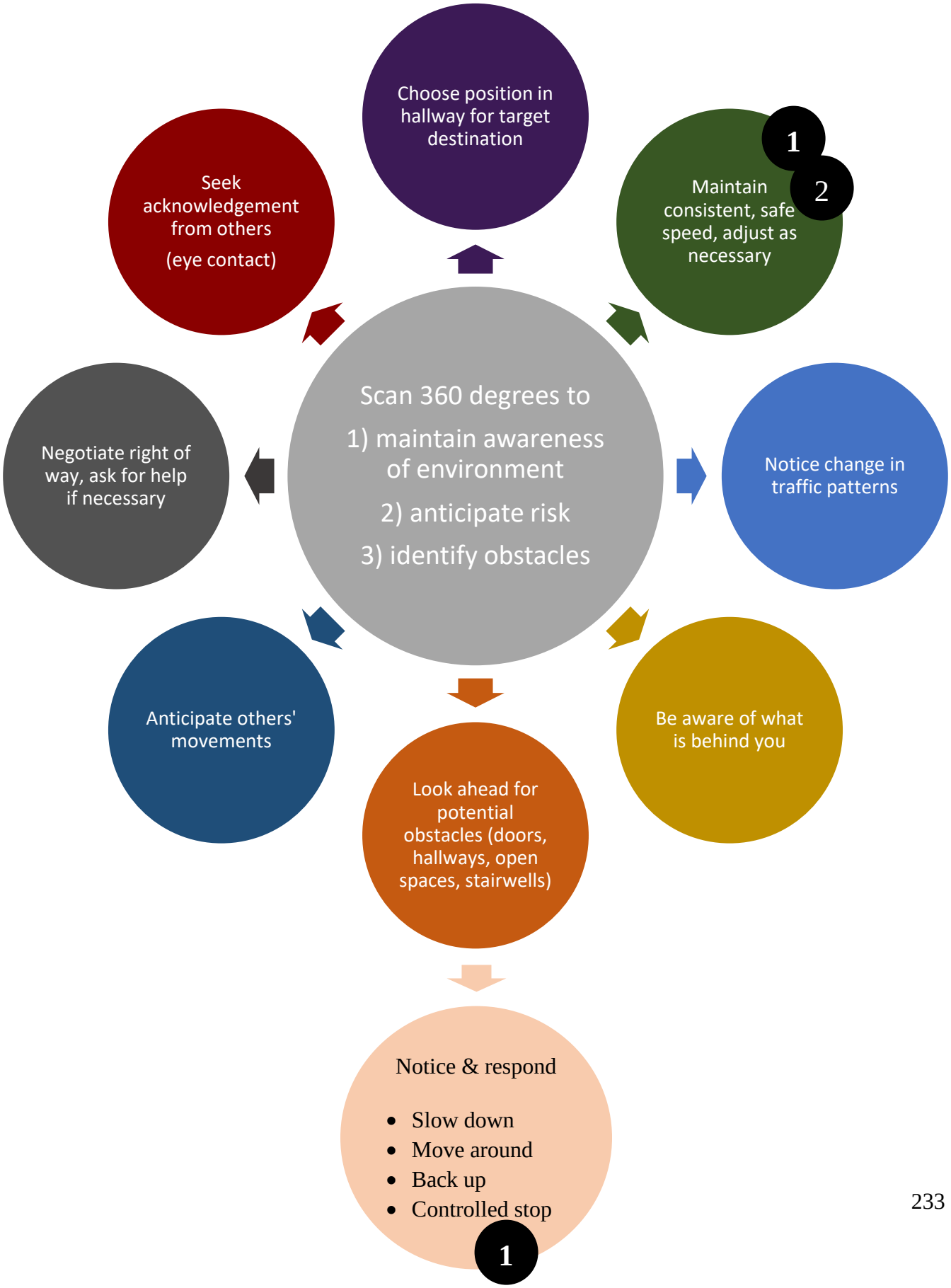


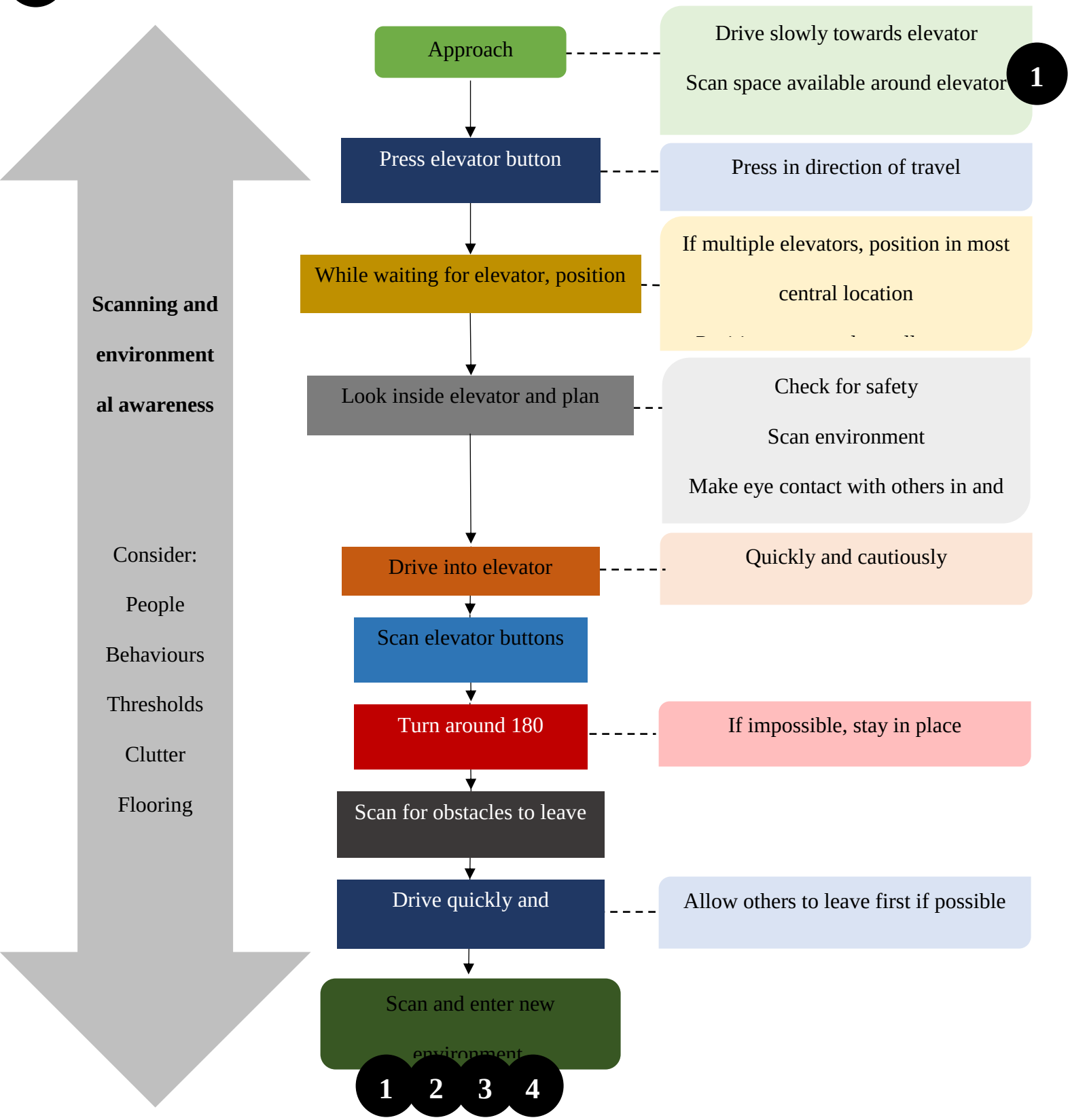
2 90 degree turns moving forward, left or right



3 90 degree turns moving backward, left or right




Choose position in hallway for target destination
Maintain consistent, safe speed, adjust as necessary
1
2
Notice change in traffic patterns
Be aware of what is behind you
Look ahead for potential obstacles (doors, hallways, open spaces, stairwells)
Anticipate others' movements
Negotiate right of way, ask for help if necessary
Seek acknowledgement from others
(eye contact)
Scan 360 degrees to
1) maintain awareness of environment
2) anticipate risk
3) identify obstacles
Notice & respond
• Slow down
• Move around
• Back up
• Controlled stop
1


Scanning and environmental awareness
Consider:
People
Behaviours
Thresholds
Clutter
Flooring
Approach
Drive slowly towards elevator
Scan space available around elevator
1
Press elevator button
Press in direction of travel
While waiting for elevator, position
If multiple elevators, position in most central location
Look inside elevator and plan
Check for safety
Scan environment
Make eye contact with others in and
Drive into elevator
Quickly and cautiously
Scan elevator buttons
Turn around 180
If impossible, stay in place
Scan for obstacles to leave
Drive quickly and
Allow others to leave first if possible
Scan and enter new environment
1 2 3 4

6 Getting through a hinged door

Scanning and environmental awareness

Consider:

People

Behaviours

Thresholds

Clutter

Flooring

Approach door **1**

Scan environment

Note type of door, threshold, and

Position chair near door

Stop chair in front of door

Consider position of feet and

Reach and grasp door handle

Stabilize body

What

Pull

Push

Pull door open by holding handle and

Push door open with body and/or chair

Consider weight of door

Easy vs. difficult swing

Plan approach to new

Scan new environment

Drive slowly through

Turn 180 degrees to face

To pull closed: Position inside frame

To push closed: Position outside

Grasp handle and drive forward/backwards to

1 2 3 4 7

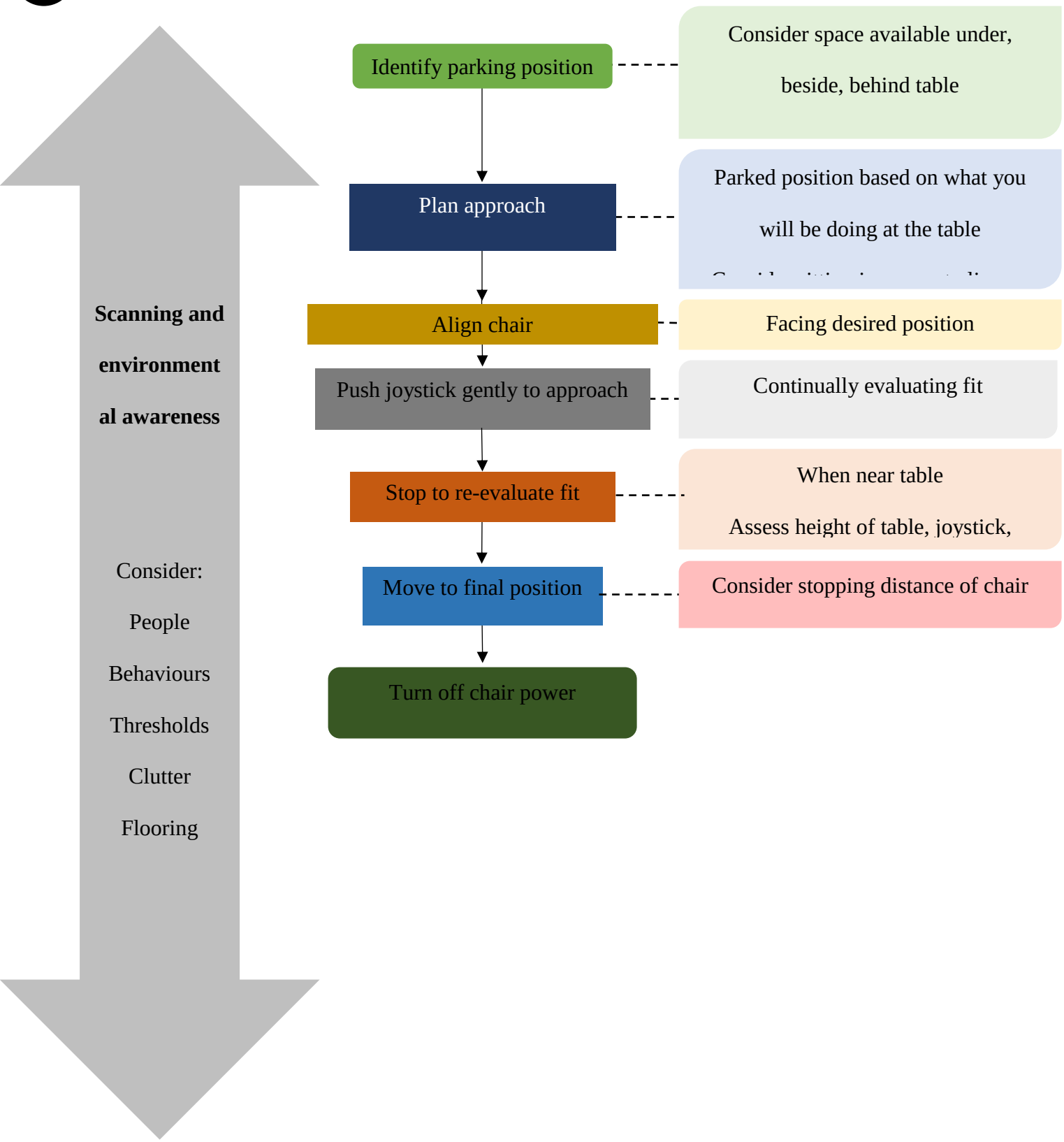
Important Skills/Abilities

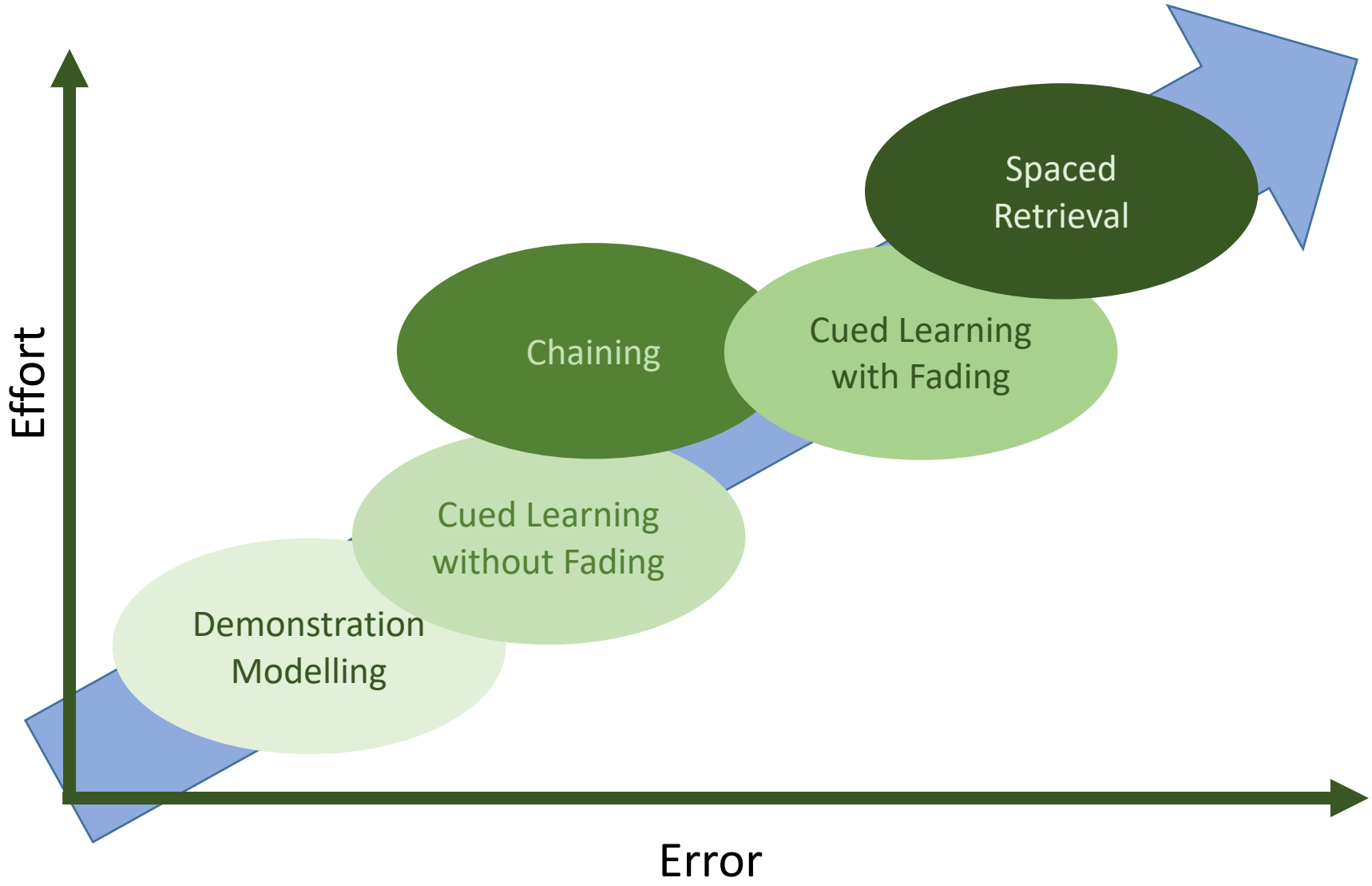
Problem solving
Vision
Proprioception
Path planning
Awareness
Judgement
Calibration
Fine motor
Body awareness

Important Knowledge

Wheelchair response to flooring
Driving characteristics of wheelchair (speed, sensitivity, stopping distance)
Wheelchair footprint
Driving etiquette/conventions
Appropriate speed for environment
Characteristics of the environment
How to stop your chair
How to operate your joystick

7 Parking at a table




Effort
Error
Demonstration Modelling
Cued Learning without Fading
Chaining
Cued Learning with Fading
Spaced Retrieval

Application of Specific Training Techniques for Skill Progression

Name of Skill: Planned and Anticipated Stop

Description of Skill: The wheelchair user is able to safely bring the wheelchair to a stop while driving in a straight line, at a location pre-determined by the wheelchair user or trainer.

Training Technique:	Demonstration/Modelling	
Learning Style:	Level of Error: Low	Level of Effort: Low
CoPILOT Mode:	Proportional	
Procedure:	1) Drive the participant straight forward in proportional mode, providing verbal and visual cues as to where you plan to stop. 2) Tell the participant you are going to remove your hand from the joystick, immediately prior to the stopping location. 3) Remove your finger from the joystick and allow the wheelchair to come to a complete stop.	
Modifications	You may wish to show the participant your joystick as you move, if they learn best with visual cues.	
Notes:	Ensure the speed of the wheelchair is appropriate for your own driving capabilities as a trainer.	

Training Technique:	Cued Learning Without/With Fading	
Learning Style:	Level of Error: Low/Medium	Level of Effort: Low/Medium
CoPILOT Mode:	Direction Only	
Procedure:	1) Point out the position where you would like the participant to drive towards and stop. Continue to remind the participant of this position as they drive. 2) Instruct the participant to push forward on their joystick. 3) If you are working only on stopping, you may wish to use the CoPILOT remote to keep the participant going in a straight line by providing gentle re-direction. 4) When the participant is approaching the position, remind them that when they reach the location, they will remove their hand from the joystick to stop. 5) At the location, say “hands off” or “remove your hand” or “stop here” depending on the skill level of the learner.	
Modifications	As the participant gains skills in planned stops, gradually fade the cues which are provided to those which are necessary.	
Notes:	In the early learning stages, you may wish to use the global speed control to limit the participant’s overall speed.	

Training Technique:	Chaining	
Learning Style:	Level of Error: Medium	Level of Effort: Medium
CoPILOT Mode:	Proportional	
Procedure	Not applicable for this skill.	
Modifications		
Notes:		

Training Technique:	Spaced Retrieval	
Learning Style:	Level of Error: High	Level of Effort: High
CoPILOT Mode:	Direction Only	
Procedure	1) Ask the participant to stop while completing tasks regularly throughout the training session. 2) In subsequent sessions, ask the participant to stop less frequently. 3) As the participant gains competence, ask the participant to stop only when it is natural to do so in the lesson.	
Modifications	If the participant begins to make errors, increase the frequency with which the skill is practiced, or revert to training methods which are seen earlier on the progression of techniques (e.g., cued learning with fading).	
Notes:	Once the participant has reached the level of spaced retrieval, the CoPILOT remote should be used primarily to prevent collisions or adverse events, rather than to provide specific directional input.	

Name of Skill: Unplanned Stop: Hands Off

Description of Skill: The wheelchair user is able to safely bring the wheelchair to a stop while driving in a straight line, at random times as requested by the trainer, or to avoid a collision.

Training Technique:	Demonstration/Modelling	
Learning Style:	Level of Error: Low	Level of Effort: Low
CoPILOT Mode:	Proportional	
Procedure:	1) Drive the participant straight forward in proportional mode, walking beside them. 2) Demonstrate the “hands off” movement (hand clearly off the joystick) as you tell the participant you are stopping.	
Modifications	You may wish to show the participant your joystick as you move, if they learn best with visual cues.	
Notes:	Ensure the speed of the wheelchair is appropriate for your own driving capabilities as a trainer.	

Training Technique:	Cued Learning Without/With Fading	
Learning Style:	Level of Error: Low/Medium	Level of Effort: Low/Medium
CoPILOT Mode:	Direction Only	
Procedure:	1) Instruct the participant to push forward on their joystick. 2) If you are working only on stopping, you may wish to use the CoPILOT remote to keep the participant going in a straight line by providing gentle re-direction. 3) At regular times throughout the forward movement, say “hands off” or “stop” depending on the skill level of the learner. 4) If the participant does not stop, activate the emergency stop trigger to demonstrate a full and complete stop.	
Modifications	As the participant gains skills in unplanned stops, gradually fade the cues which are provided to those which are necessary.	
Notes:	In the early learning stages, you may wish to use the global speed control to limit the participant’s overall speed.	

Training Technique:	Chaining	
Learning Style:	Level of Error: Medium	Level of Effort: Medium
CoPILOT Mode:	Proportional	
Procedure	Not applicable for this skill.	
Modifications		
Notes:		

Training Technique:	Spaced Retrieval	
Learning Style:	Level of Error: High	Level of Effort: High
CoPILOT Mode:	Direction Only	
Procedure	5) Ask the participant to stop unexpectedly while completing tasks regularly throughout the training session. 6) In subsequent sessions, ask the participant to stop less frequently. 7) As the participant gains competence, ask the participant to stop only when it is natural to do so in the lesson.	
Modifications	If the participant begins to make errors, increase the frequency with which the skill is practiced, or revert to training methods which are seen earlier on the progression of techniques (e.g., cued learning with fading).	
Notes:	Once the participant has reached the level of spaced retrieval, the CoPILOT remote should be used primarily to prevent collisions or adverse events, rather than to provide specific directional input.	

Name of Skill: Emergency Stops to Avoid Collision: Pull Back

Description of Skill: The wheelchair user is able to quickly and safely bring the wheelchair to a stop while driving forward to avoid a collision.

Training Technique:	Demonstration/Modelling	
Learning Style:	Level of Error: Low	Level of Effort: Low
CoPILOT Mode:	Proportional	
Procedure:	1) Drive the participant straight forward in proportional mode, providing verbal and visual cues as to where you plan to stop. 2) While showing the participant your joystick, pull back on the joystick to demonstrate a quick stop.	
Modifications	You may wish to show the participant your joystick as you move, if they learn best with visual cues. This may also be demonstrated easily on the participant's joystick.	
Notes:	Ensure the speed of the wheelchair is appropriate for your own driving capabilities as a trainer.	

Training Technique:	Cued Learning Without/With Fading	
Learning Style:	Level of Error: Low/Medium	Level of Effort: Low/Medium
CoPILOT Mode:	Direction Only	
Procedure:	1) Instruct the participant to push forward on their joystick, providing hand over hand guidance if necessary. 2) If you are working only on stopping, you may wish to use the CoPILOT remote to keep the participant going in a straight line by providing gentle re-direction. 3) Ask the participant to "pull back on the joystick" when you want them to stop. 4) If the participant does not immediately stop, activate the emergency stop trigger.	
Modifications	As the participant gains skills in planned stops, gradually fade the cues which are provided to those which are necessary.	
Notes:	In the early learning stages, you may wish to use the global speed control to limit the participant's overall speed.	

Training Technique:	Chaining	
Learning Style:	Level of Error: Medium	Level of Effort: Medium
CoPILOT Mode:	Proportional	
Procedure	Not applicable for this skill.	
Modifications		
Notes:		

Training Technique:	Spaced Retrieval	
Learning Style:	Level of Error: High	Level of Effort: High
CoPILOT Mode:	Direction Only	
Procedure	1) Ask the participant to pull back on the joystick while completing tasks regularly throughout the training session. 4) In subsequent sessions, ask the participant to stop less frequently. 5) As the participant gains competence, ask the participant to pull back only when it is natural to do so in the lesson (imminent collision).	
Modifications	If the participant begins to make errors, increase the frequency with which the skill is practiced, or revert to training methods which are seen earlier on the progression of techniques (e.g., cued learning with fading).	
Notes:	Once the participant has reached the level of spaced retrieval, the CoPILOT remote should be used primarily to prevent collisions or adverse events, rather than to provide specific directional input.	

Name of Skill: Driving forward in a straight line

Description of Skill: The wheelchair user is able to drive in a straight line through a non-congested space.

Training Technique:	Demonstration/Modelling	
Learning Style:	Level of Error: Low	Level of Effort: Low
CoPILOT Mode:	Proportional	
Procedure:	1) Drive the participant straight forward in proportional mode, walking beside them. 2) Provide cues as to how you are pushing on the joystick (straight forward), and how you are maintaining your alignment in the hallway (provide visual landmarks on the chair and hallway).	
Modifications	You may wish to show the participant your joystick as you move, if they learn best with visual cues.	
Notes:	Ensure the speed of the wheelchair is appropriate for your own driving capabilities as a trainer.	

Training Technique:	Cued Learning Without/With Fading	
Learning Style:	Level of Error: Low/Medium	Level of Effort: Low/Medium
CoPILOT Mode:	Direction Only	
Procedure:	1) Instruct the participant to push forward on their joystick, providing hand over hand guidance where necessary. Continue to remind them to push forward on the joystick throughout the skill completion. 2) Using the CoPILOT remote, provide gentle direction to keep the participant moving in a forward direction. If this is required to stay straight, stop the participant when there has been a correction and explain the guidance which was provided. Give the participant suggestions for staying straight on the next attempt. 3) Continually remind the participant to press forward on the joystick straight forward. Provide verbal instruction for adjustment where necessary (move your joystick a little towards me, a little away from the wall etc.). Wherever possible use visual cues rather than left and right. 4) Remind the participant regularly of the things they should be observing in the same (location in space, potential obstacles, visual cues).	
Modifications	As the participant gains skills in driving forward, gradually fade the cues which are provided to those which are necessary.	

Notes:	In the early learning stages, you may wish to use the global speed control to limit the participant's overall speed. The emergency stop trigger should be used to prevent collisions.

Training Technique:	Chaining	
Learning Style:	Level of Error: Medium	Level of Effort: Medium
CoPILOT Mode:	Proportional	
Procedure	As there are multiple requirements for this skill (motor, cognitive, perceptual), you may wish to split these up to reduce cognitive load. 1) For initial motor skill learning, do not focus highly on the things the participant should be looking at or for, or other cues in the environment. Use the CoPILOT remote to avoid collisions where necessary. 2) For perceptual skills, use the CoPILOT remote to drive the wheelchair, while the wheelchair user provides feedback about their position in space. 3) For cognitive skills, use the CoPILOT remote to drive the wheelchair, while the wheelchair user provides feedback about anticipated obstacles, or potential challenges in the environment.	
Modifications		
Notes	This skill may be graded by maintaining a low speed to begin with and increasing throughout the learning process.	

Training Technique:	Spaced Retrieval	
Learning Style:	Level of Error: High	Level of Effort: High
CoPILOT Mode:	Direction Only	
Procedure	Not applicable for this skill – driving forward is a component of most wheelchair driving therefore will be practiced regularly.	
Modifications		
Notes:		

Name of Skill: Proportional control of speed

Description of Skill: The wheelchair user is able to control the speed through modulation of their force on the joystick.

Training Technique:	Demonstration/Modelling	
Learning Style:	Level of Error: Low	Level of Effort: Low
CoPILOT Mode:	Proportional	
Procedure:	1) Drive the wheelchair forward demonstrating slower and faster movements and providing verbal or visual cues as to how this is accomplished. 2) Explain the joystick as a gas pedal, where the further you push forward, the faster the chair will go.	
Modifications	You may wish to show the participant your joystick as you move, if they learn best with visual cues.	
Notes:	Ensure the speed of the wheelchair is appropriate for your own driving capabilities as a trainer.	

Training Technique:	Cued Learning Without/With Fading	
Learning Style:	Level of Error: Low/Medium	Level of Effort: Low/Medium
CoPILOT Mode:	Direction Only	
Procedure:	1) Instruct the participant to push gently on the joystick until the chair begins to move and maintain that speed (crawling) by continuing to push gently. 2) Provide verbal cues to increase speed by pushing further on the joystick. 3) When you want the participant to slow down, instruct the participant to push less on the joystick, or to pull their hand back slightly. 4) Continue to provide specific hand related cues to modulate speed throughout driving practice. 5) While the participant is driving, provide directional input to keep the participant on a straight path. 6) If the participant does not slow down when asked, you may use the global speed controls to reduce speed, and then provide additional feedback to the participant.	
Modifications	As the participant gains skills in speed modulation, gradually fade the cues which are provided to those which are necessary.	
Notes:	The emergency stop trigger should be used to prevent collisions.	

Training Technique:	Chaining	
Learning Style:	Level of Error: Medium	Level of Effort: Medium
CoPILOT Mode:	Direction Only	
Procedure	To reduce cognitive load, work with the participant on achieving speed control without concern for direction by using the CoPILOT remote in directional mode, while the participant controls speed using the joystick. As the participant gains more experience with speed control, gradually reduce the amount of input you provide for directional control.	
Modifications		
Notes	This requires consistent trainer vigilance to maintain direction control.	

Training Technique:	Spaced Retrieval	
Learning Style:	Level of Error: High	Level of Effort: High
CoPILOT Mode:	Direction Only	
Procedure	Not applicable for this skill – speed control is a component of most wheelchair driving therefore will be practiced regularly.	
Modifications		
Notes:		

Name of Skill: Turning moving forward

Description of Skill: The wheelchair user is able to execute a right or left turn moving forward with no contact with walls or other obstacles.

Training Technique:	Demonstration/Modelling	
Learning Style:	Level of Error: Low	Level of Effort: Low
CoPILOT Mode:	Proportional	
Procedure:	1) Provide a demonstration of a right turn around a corner. 2) Identify the location where you initiate the turn using points on the wheelchair user's body or chair as reference points. 3) Explain the contact you are making with the joystick ("I am pushing directly towards the wall" 4) Straighten the chair, providing feedback about how you are bringing the joystick back to centre while pushing forward.	
Modifications	You may wish to show the participant your joystick as you move, if they learn best with visual cues.	
Notes:	Ensure the speed of the wheelchair is appropriate for your own driving capabilities as a trainer.	

Training Technique:	Cued Learning Without/With Fading	
Learning Style:	Level of Error: Low/Medium	Level of Effort: Low/Medium
CoPILOT Mode:	Direction Only	
Procedure:	Review the task analysis for turning while moving forward and use cues throughout. 1) As the participant nears the turn, remind them of the landmarks/cues they will use to identify when to make the turn. 2) As they approach the initiation, provide verbal cues instructing them to line up the landmark with the corner and "turn now" by "push sideways on the joystick towards the wall" 3) Use the CoPILOT remote if necessary, to help complete the turn, providing verbal feedback as you go. 4) Remind the participant to scan the new environment as they enter and straighten out the joystick to keep driving forward.	
Modifications	As the participant gains skills in turning, gradually fade the cues which are provided to those which are necessary.	

Notes:	In the early learning stages, you may wish to use the global speed control to limit the participant's overall speed. The emergency stop trigger should be used to prevent collisions.

Training Technique:	Chaining	
Learning Style:	Level of Error: Medium	Level of Effort: Medium
CoPILOT Mode:	Proportional	
Procedure	Review the task analysis (2) for turns while moving forward to stablish steps required to complete the turn. 1) Forward Chaining: Begin by having the participant complete 1-2 steps as outlined above, with the trainer completing the remainder of the steps while providing cues. Gradually increase the number of steps completed by the wheelchair user until they are completing the entire skill unassisted (or with minimal assistance). 2) Backward chaining: Begin by having the trainer complete all but 1-2 steps as outlined above, with the wheelchair user completing the last 1-2 steps while the trainer provides cues. Gradually increase the number of steps (working backwards) completed by the wheelchair user until they are completing the entire skill unassisted (or with minimal assistance).	
Modifications	If the participant is skilled at both early and late steps, or steps in the middle, the trainer may modify which portions of the skill they complete to ensure a successful experience.	
Notes	This skill may be graded by maintaining a low speed to begin with and increasing throughout the learning process.	

Training Technique:	Spaced Retrieval	
Learning Style:	Level of Error: High	Level of Effort: High
CoPILOT Mode:	Direction Only	
Procedure	During initial training, identify locations for turns often to ensure the skill is repeated regularly. As the participant gains proficiency, reduce the number of turns completed gradually until only those which are relevant to the specific task are completed.	
Modifications		
Notes:		

Name of Skill: Navigating in Congested Areas

Description of Skill: The wheelchair user is able to safely navigate a congested area with no collisions.

Training Technique:	Demonstration/Modelling	
Learning Style:	Level of Error: Low	Level of Effort: Low
CoPILOT Mode:	Proportional	
Procedure:	1) Drive the wheelchair through a congested area, noting any obstacles you face and your plan to avoid or move around. 2) Provide continual cueing and information to the participant as you navigate through the space.	
Modifications		
Notes:	The desired outcome of this demonstration is a reduction in anxiety for the participant associated with crowded or congested areas. To that end, the trainer should maintain caution and a slow speed to provide an appropriate demonstration.	

Training Technique:	Cued Learning Without/With Fading	
Learning Style:	Level of Error: Low/Medium	Level of Effort: Low/Medium
CoPILOT Mode:	Direction Only	
Procedure:	Review the task analysis for navigating in a congested space above. 1) Instruct the participant to drive slowly (you may reduce their speed when learning) through the crowded space. 2) Continually draw their attention to potential obstacles, things they may wish to be attending to, scanning etc. 3) If you note potential obstacles or situations which may be difficult to navigate, as the participant to stop to problem solve together. 4) Continue to provide cues as to how to navigate around obstacles, speaking to methods to move the joystick in the correct direction, as well as to the cognitive and perceptual skills required.	
Modifications	As the participant gains skills navigating, gradually fade the cues which are provided to those which are necessary.	
Notes:	In the early learning stages, you may wish to use the global speed control to limit the participant's overall speed. The emergency stop trigger should be used to prevent collisions.	

Training Technique:	Chaining	
Learning Style:	Level of Error: Medium	Level of Effort: Medium
CoPILOT Mode:	Proportional	
Procedure	1) As there are multiple requirements for this skill (see task analysis above), you may wish to split these up to reduce cognitive load. 2) For each of the areas of focus in the task analysis, you may wish to have the participant provide feedback and focus on one at a time to begin. 3) When beginning this skill, discuss potential obstacles in the space with the participant before you begin driving through the space, including how to overcome them. 4) You may drive the wheelchair through the space and ask the participant to cue you to particular items, including things they see, hear, and notice, according to the task analysis above. 5) Once the participant gains competence at identifying or attending to multiple areas, begin to combine those areas so they are required to attend to two or more items at a time. 6) Introduce the participant's own speed control gradually, with the CoPILOT remote in Direction Only mode to provide assistance with direction. 7) As the participant takes on directional control in the environment, provide guidance where necessary with the CoPILOT remote in direction only mode.	
Modifications	The order of the steps above may be modified based on the participant's strengths and challenges in the environment. Begin by capitalizing on those skills which are strengths, gradually adding those skills which are more difficult.	
Notes	This skill may be graded by maintaining a low speed to begin with and increasing throughout the learning process.	

Training Technique:	Spaced Retrieval	
Learning Style:	Level of Error: High	Level of Effort: High
CoPILOT Mode:	Direction Only	
Procedure	Not applicable for this skill – navigating congested areas is a component of most wheelchair driving therefore will be practiced regularly.	
Modifications		
Notes:		

Appendix G WSP Training Manual

CoPILOT

Collaborative Power mobility Innovative Learning OpporTunity

Trainer Manual

Wheelchair Skills Program Intervention

Introduction

Welcome to the Wheelchair Skills Program Intervention Training Manual for the CoPILOT Study. As a trainer for this intervention, you will be responsible for delivering the WSP as it is outlined in the WSP Manual (separate).

The following document will guide you through the research protocol requirements, with a small amount of information provided from the WSP manual.

Contact Information

If you encounter any difficulties during your training period, or have any questions please send an email to:

Emma Smith

OR

Erica Digby

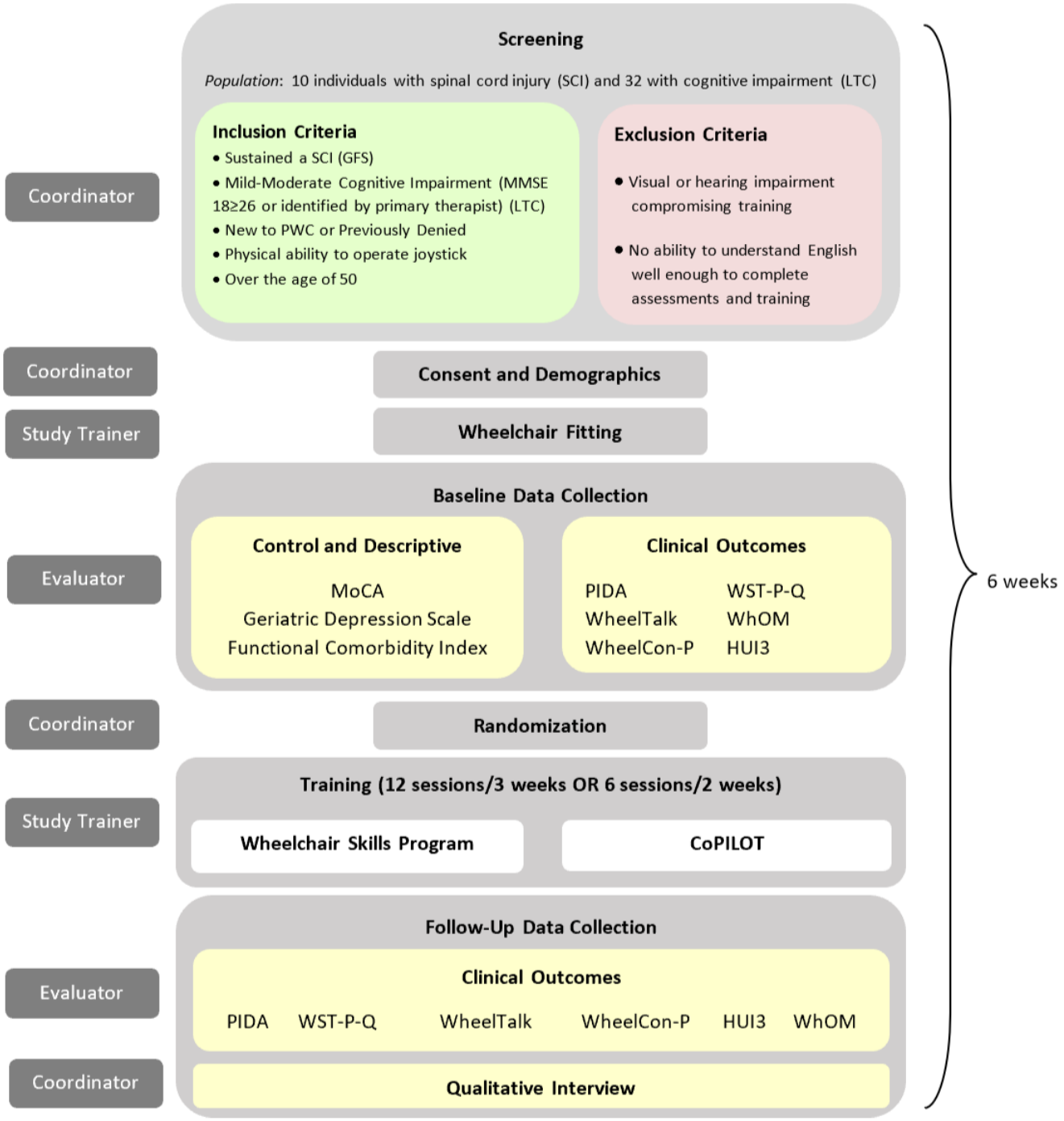
If you have a situation which requires a more immediate response (see Emergency Procedures section), please contact as soon as possible:

Emma Smith

OR

Erica Digby

Overview of the CoPILOT Study



Prior to Training

Documentation

Prior to the first training session, trainers will be provided with copies of the following documentation and results of the participant's baseline evaluation:

e) Chart Summary (Appendix A): Includes information about the participant's condition, transfer status, and any relevant information regarding the participant's training needs.
f) Wheelchair Fitting Form (Appendix B): This is provided for the trainer's awareness and may be used to record any changes which are made to the user's seating position during the training program.
g) MoCA Assessment Score Report (Appendix C)
h) Wheelchair Skills Test Summary Report (Appendix D)

Scheduling

When the trainer is assigned to a participant, the research coordinator will work with the trainer and participant to identify a minimum of one week (four sessions) of training times. During the first training session, the trainer may work collaboratively with the client to identify additional training times for the second and third week. Trainers should expect to begin 15 minutes prior to the scheduled training time, and plan for an additional 15 minutes at the end if required to complete documentation or wrap-up.

Consent Monitoring

Participants in this study may be experiencing conditions which impact their ability to consent to treatment. For individuals who are unable to consent, we will be using a process of legal consent from the substitute decision maker, and a process of assent by the participant.

Due to potential challenges with memory loss, we will also be using ongoing consent monitoring to ensure participants continue to consent to treatment. Therefore, as with any clinical intervention, trainers should obtain verbal consent from the participant at the outset of each training session and monitor the participant throughout for any verbal or physical (body language) signs that they no longer wish to consent. These should be recorded by the trainer for discussion with the team in the Wheelchair Skills Training Log (Appendix F) following each session.

Training

Overview

- Participants allocated to the Wheelchair Skills Program Intervention will receive the study intervention protocol from a CoPILOT study therapist four times per week for a total of 3 weeks, OR three times per week for a total of two weeks.
- Participants will receive all other rehabilitation treatments available to them at the facility where they are residing. This will not be monitored.
- Prior to starting training, participants will complete baseline assessments with a study evaluator and be fitted for a powered wheelchair by a study therapist or study coordinator.
- Following the study, participants will be re-assessed by a study evaluator. It is very important the assessor does not know which group the participant was assigned to. Trainers and participants must not disclose this information at any time when the evaluators may be present.
- To maintain the integrity of the study, please do not share with others the protocol your participant has been assigned to. At the completion of the study, the results will be formally disseminated.

Training Schedule

Each participant will receive 6 or 12 training sessions, at a maximum of one hour per session. Training sessions should occur four times per week for three weeks, or three times per week for two weeks. Sessions missed should be made up within the week if possible or recorded if not possible on the Study Trainer Follow-Up Report (Appendix E).

Training Location

All training will take place at GF Strong Rehabilitation Centre, or a long-term care centre in the lower mainland. Trainers will meet the participant in a location of the participant's choice, taking into account transfer needs into the powered wheelchair. Initial training sessions should take place in a quiet area with minimal obstacles, and progress to more complex environments as the participant's skill increases. If training takes place in the wheelchair skills room, trainers will require the code for the door.

Training Session Content

Content of the training sessions will be delivered according to the principles and skills outlined in the Wheelchair Skills Training Program (WSTP) Manual (specifically Chapters 5-8, and Appendices 1 and 2). Full text of the WSTP Manual will be provided to you.

The WSTP provides specific training tips for each of the component skills covered in the program, as well as instruction on types of practice and training approach. These follow motor learning principles.

Training Goals should be reviewed with the participant in the first session.

Training Principles

Motor Skills Learning: The WSP was developed based on the principles of Motor Skills Learning theory. The WSP describes the learning process according to Motor Skills Learning Theories as follows: "As the learning progresses, preliminary success is eventually achieved (skill acquisition), consistency within training sessions improves, success carries over into subsequent sessions (skill retention and the learner is able to use the skill in more diverse settings (skill transfer). "

The following principles should be considered during training (further detail available in the WSP Manual):

- Goal Setting
- Individualize the training process
- Structure of training
- Trainer to trainee ratio
- Motivation
- Demonstration
- Verbal instructions
- Focus of Attention
- Imagery
- Feedback (type, content, timing)
- Specificity of practice
- Amount and variability of practice
- Distribution of practice
- Whole vs. Part practice
- Simplification and Progression

Training Session Structure

The WSTP outlines a suggested training session structure as follows:

a) Welcome and Warm Up (5 minutes)
    a. Check status
    b. Review goals and planned activities
    c. Questions and answers
    d. Warm up activity
b) Practice Skills that have already been acquired but need work (10 minutes – may be extended)
    a. Random order, beginning with less stressful skills
    b. Variety of settings
    c. Trainer provides structure, safety, minimal feedback
    d. Games can be included
c) Practice skill that has not been acquired yet (10 minutes – may be extended)
    a. Trainer provides structure, safety, instructions, demonstration, and feedback
d) Closing (5 minutes)
    a. Questions and answers
    b. Plan next session content
    c. Assign homework
    d. Schedule next session
    e. Complete any required documentation

Skill Categorization:

The WSTP categorizes skills into the following groupings:

- How to operate parts of the wheelchair
- Understanding the dimensions of the wheelchair
- Getting into, out of, and repositioning oneself with respect to the wheelchair
- Moving the wheelchair around on smooth level surfaces
- Using the environment
- Skills that require leaning in the wheelchair
- Skills that require popping the front wheels briefly off the surface
- Working with a helper

Component Skills:

The WSTP training program is based on training of 30 specific component skills. Each of these should be introduced as the trainer feels it is appropriate and safe to do so.

A sample progression is provided below, modified from the MWC skill progression in the WSP Manual. This has been adjusted to accommodate additional training sessions (up to 12):

Skill	Session #					
	1-2	3-4	5-6	7-8	9-10	11-12
1. Moves controller away and back	New	Old				
2. Turns power on and off	New	Old				
3. Selects drive modes and speeds	New	Old				
4. Disengages and engages motors	New	Old				
5. Operates battery charger	New	Old				
6. Rolls forward short distance	New	Old				
7. Rolls backwards short distance		New	Old			
8. Turns in place		New	Old			
9. Turns while moving forwards		New	Old			
10. Turns while moving backwards		New	Old			
11. Maneuvers sideways		New	Old			
12. Reaches high object			New	Old		
13. Picks object from floor			New	Old		
14. Relieves weight from buttocks			New	Old		
15. Operates body positioning options			New	Old		
16. Level transfer			New	Old		
17. Gets through hinged door				New	Old	
18. Rolls longer distance				New	Old	
19. Avoids moving obstacles				New	Old	
20. Ascends slight incline				New	Old	
21. Descends slight incline				New	Old	
22. Ascends steep incline					New	Old
23. Descends steep incline					New	Old
24. Rolls across side-slope					New	Old
25. Rolls on soft surface					New	Old
26. Gets over threshold					New	Old
27. Gets over gap						New
28. Ascends low curb						New
29. Descends low curb						New
30. Gets from ground into wheelchair						New

Spotting and Maintaining Safety

While training, the trainer should be in a position to turn off the wheelchair if there is imminent risk to the wheelchair user, trainer, or others in the environment, or to change direction of the wheelchair by assuming control of the joystick.

Participants should be using safety belts while driving, and the trainer should adhere to all spotting principles outlined in the WSTP manual. Trainers should maintain awareness of the participant's capabilities and may increase distance between the user and the trainer as competence increases.

The WSP Manual outlines potential safety risks and how to address these in the training process.

Documentation of Training

Following each training session, the trainer is requested to fill out the Wheelchair Skills Training Log (Appendix F) on the study tablet or at home using the Qualtrics (link: https://ubc.ca1.qualtrics.com/jfe/form/SV_6orl6DmcJe3VvSJ).

Following the completion of all training sessions for the participant, the trainer is requested to fill out the Study Trainer Follow-Up Report (Appendix E) on the study tablet or at home using the Qualtrics (link: https://ubc.ca1.qualtrics.com/jfe/form/SV_6orl6DmcJe3VvSJ).

To log into the survey, open a browser on the tablet provided for training documentation and use the links above. You must be in a Wi-Fi enabled zone to access the links. Alternately you may complete these from home on your own device using the links above.

Emergency Procedures and Adverse Events

In the event of an emergency, your first responsibility is to ensure the participant is safe. The following procedures should be followed in the event of an emergency.

Participant Illness: In the event the participant becomes ill during the training session, or reports feeling unwell, offer the participant the opportunity to conclude the training session and return to their room. Notify the nursing station in the participant's unit on your return, complete an Adverse Event form (Appendix G) and record this information in the daily training log.

Participant Fall: If a participant sustains a fall while attempting any wheelchair skill or transfer, as the participant not to move until an assessment can be completed. Obtain assistance from a staff person to complete an assessment and, if possible, return the participant to their chair. Offer the participant the opportunity to conclude the training session and return to their room. Notify the nursing station in the participant's unit on your return, complete an Adverse Event form (Appendix G) and record this information in the daily training log.

Autonomic Dysreflexia: Autonomic dysreflexia is a condition where there is a sudden onset of high blood pressure. It is most common in individuals with T6 or higher spinal cord injury. This is a potentially life-threatening condition. Observe the participant for the following symptoms while completing training:

- Intense headache
- Profuse sweating
- Flushed face
- Goosebumps
- Apprehension
- Blurred vision

If you notice a sudden onset of these symptoms, or they are reported to you by the participant, ensure the participant is in an upright position, there are no kinks in the catheter (if applicable), and obtain assistance from facility staff to assess the participant. Notify the nursing station in the participant's unit on your return, complete an Adverse Event form (Appendix G) and record this information in the daily training log.

If the participant is in significant distress, or becomes non-responsive, follow procedures for Code Blue below.

Code Blue: Cardiac or Respiratory Distress, Non-responsive Participant: In the event of significant cardiac or respiratory distress, or a non-responsive participant, we will follow facility specified Code Blue procedures as follows:

5) Dial “333” from any telephone at GF Strong to reach the front receptionist and report a “CODE BLUE” and your location (e.g., Basement, Wheelchair Skills Room; First Floor, Gym);
6) Repeat to the front receptionist
7) Ask the receptionist to repeat
8) Administer First Aid if you are qualified until help arrives

CODE RED: Fire or Fire Alarm*:* We are required to follow established Fire procedures while working at GF Strong:

If the Fire is in your area:

5) Ensure anyone in the area is safe
6) Pull the fire alarm
7) Dial 9-911 from any GFS phone and tell the operator there is a fire at GF Strong in your location (describe location including floor of building). The address is 4255 Laurel St.
8) Evacuate or extinguish if safe to do so

If the fire bell rings:

5) Listen to the PA announcement and follow instructions.
6) If the fire is in your area, remove the participant to a safe area or outside.
7) If the fire is not in your area, remain with the participant and close all doors until it is over.
8) Follow evacuation instructions as provided on the PA system.

Additional Resources

Trainers will be provided with a full copy of the Wheelchair Skills Program Manual as a reference guide for their training. They may also access additional training resources on the Wheelchair Skills Program webpage at www.wheelchairskillsprogram.ca.

Chart Summary

Participant ID: _____ Date of Initial Chart Review: _____

Diagnosis:

Date of Onset or Injury:

Current functional status (including mobility):

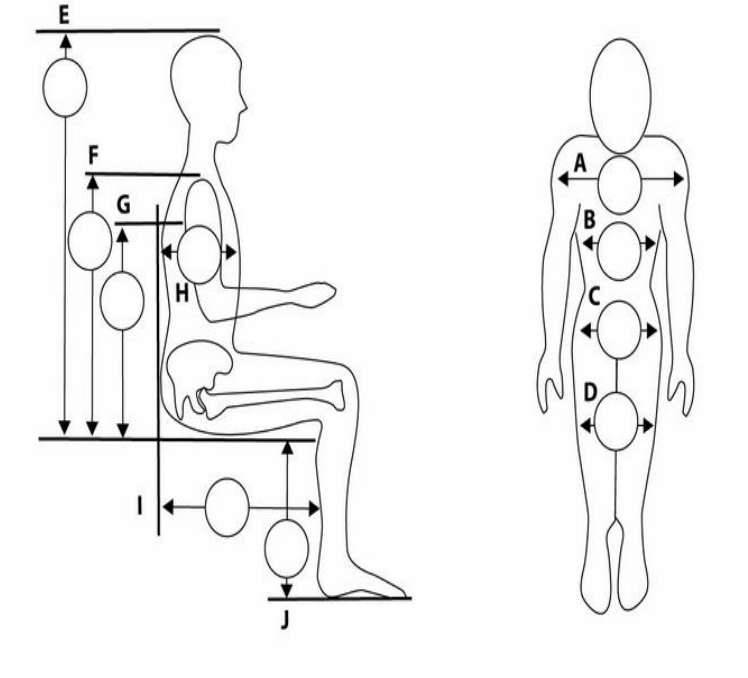
Cognition Status (including capacity to consent to treatment):

Transfer status

Date	Status

Wheelchair Fitting Form

Participant ID: _____ Rater: _____ Date: _____



Measurements

K. Width of Shoulders _____in
L. Width of back _____in
M. Hip width _____in
N. Knee width _____in
O. Height to top of head _____in
P. Height to shoulder _____in
Q. Height to Axilla _____in
R. Depth of torso _____in
S. Upper leg length _____in
T. Lower leg length _____in

Range of Motion

5. Hip range _____◦
6. Knee range _____◦
7. Ankle range _____◦
8. Neck range _____◦

Postural Tendencies

7. Scoliosis
    a. Present Y/N
        i. Convex to R/L
8. Kyphosis
    a. Present Y/N
        i. Fixed/Flexible
        ii. Level
9. Lordosis
    a. Present Y/N
        i. Fixed/Flexible
        ii. Level
10. Hip Rotation
    a. Present Y/N
        i. Hip Forward R/L
        ii. Fixed/Flexible
11. Trunk Rotation
    a. Present Y/N
        i. Shoulder Forward R/L
        ii. Fixed/Flexible
12. Obliquity
    a. Present Y/N
        i. Hip high R/L
        ii. Fixed/Flexible

Notes:

_____

_____

MoCA Assessment Report

Image of participant worksheet

Specific Scores

Item	Score	Item	Score
Attention: Forward digit span	/1	Abstraction	/2
Attention: Backward digit span	/1	Delayed Recall	/5
Vigilance	/1	Orientation	/6
Serial 7 Subtraction	/3		
Language: Repetition	/2		
Language: Fluency	/1		

Comments/Expected Impact on Training:

Wheelchair Skills Assessment Summary

Power Mobility Indoor Driving Assessment

Item	Applicable	Score	Comment
Bedroom			
31. Accessing bed- right			
32. Accessing bed – left			
33. Approaching dresser			
34. Approaching closet			
Bathroom			
35. Into bathroom			
36. Approaching sink			
37. Approaching Toilet			
38. Exit bathroom			
Doors			
39. Sliding doors – mat trigger			
40. Swing Open Doors – mat trigger			
41. Automatic doors – button trigger			
42. Regular doors			
Elevators			
43. Entering elevator			
44. Spacing in elevator			
45. Exiting elevator			
Parking			
46. Parking under table			
47. Parking beside table			
48. Back-in parking			
49. Parallel parking			
Ramps			
50. Up a ramp			
51. Down a ramp			
Skilled Driving			
52. Turning Right			
53. Turning left			
54. 180°Turn			
55. Driving backwards			
56. Manipulating – congested area			
57. Maneuverability			
58. Obstacles – unexpected			
59. Speed selection*			
60. Sharing public space*			

Wheelchair Skills Program Questionnaire Summary

Total Score for Capacity: /60

Skills participant feels capable of performing (Score of 2)
Skills participant feels capable of performing, but not as well as they would like (Score of 1)
Skills participant has never done, or cannot do (Score of 0)
Notes/Comments:

WheelTalk Summary

	Baseline	Dual-Task
Time (seconds)		
Number of pylons hit		
Number of letters recited		
Number of errors		

WhOM Summary

Participation Goals	Importance	Satisfaction

Wheelchair Skills Training Log

Participant Number: _____ Trainer: _____

Date		Start time		End time	

Was training missed today? Please provide a reason for the missed session.	
Skills trained	
Safety Concerns	
Equipment Issues	
Plan	

Notes and Consent Monitoring	
Which (if any) of the following factors do you think impacted your training with the participant today? Please explain.	☐ Fatigue ☐ Mood ☐ Environmental factors ☐ Pain ☐ Stresses associated with other events ☐ Training related anxiety ☐ Medications ☐ Other

Trainer Follow-Up Report

Participant Number		Trainer Name	
Training Start Date		Training End Date	

How many training sessions were completed?	
If less than 6 or 12, please provide an explanation for missed sessions:	
Please describe any challenges you faced adhering to the research protocol:	
Based on this participant, are there any protocol changes which are required prior to proceeding with the next participant?	
Please provide any other comments or issues which you would like to discuss with the team at the next meeting for inclusion on the agenda	

Adverse Event Reporting Form

Participant Number:	**Date of Adverse Event:**
Description of Event:	
Severity 1 = Mild (no training missed; able to continue participation in study) 2 = Moderate (will need to miss 1-4 training sessions; still in study) 3 = Severe (hospitalization/medical intervention required / withdrawal from CoPILOT study)	**Relationship to Intervention** 1 = Definitely related 2 = Possibly related 3 = Not related
Outcome of Adverse Event:	

Signature:	**Name/Title:**	**Date:**

Notified:	**Name:**	**Signature:**	**Date:**
○ **CoPILOT Coordinator** ○ **CoPILOT PI**			

Comments:

Appendix H CoPILOT Technical Manual

CoPILOT

Collaborative Power mobility Innovative Learning OpporTunity

Technical Manual

Changing a Chair from Standard to CoPILOT

To change the chair from standard (no OMNI+ system) to CoPILOT (with OMNI+ system), follow the steps below:

1) Turn the wheelchair off
2) Mount the OMNI+ to the wheelchair
3) Plug the OMNI system into the OMNI system cable
4) Turn the chair on. The wheelchair and OMNI+ systems will cycle through a process which will end with a green circle appearing on the screen.
5) Restart the wheelchair. The wheelchair will be driveable in Profile 7 from the wheelchair joystick without the CoPILOT system plugged in
6) To use it in CoPILOT mode, press the P button on the OMNI to get to Profile 1 once the CoPILOT system is plugged in and set up

Changing a Chair from CoPILOT to Standard

To change the chair from CoPILOT (with OMNI+ system) to standard (no OMNI+ system), follow the steps below:

1) Turn the wheelchair off
2) Un-plug the OMNI system from the OMNI system cable
3) Remove the OMNI+ from the wheelchair
4) Turn the chair on. The wheelchair and OMNI+ systems will cycle through a process which will end with two dots (2 and 4) showing on the LED Joystick screen.
5) Restart the wheelchair. The wheelchair will be driveable

Programming the Wheelchairs

To program the wheelchairs:

1) Connect the programming dongle to the wheelchair by plugging it into the joystick cable, between two plugs.
2) Using the USB cable, connect the programming dongle to the laptop
3) Turn on the wheelchair
4) To set up initial programming
    a. choose the correct file (O-Style or S-Style Initial Programming Parameters) from the M-Drive, and open the file
    b. When you see “R-Net Connected” in the bottom right corner of the program, the wheelchair is connected to the program
    c. Choose “Write to Controller” from the drop-down menu
5) To change existing programming
    a. Open the R-Net Programmer software on the laptop
    b. When you see “R-Net Connected” in the bottom right corner of the program, the wheelchair is connected to the program
    c. Choose “Read from Controller” from the drop-down menu
    d. Change any necessary parameters
    e. Choose “Write to Controller from the drop-down menu
6) Disconnect the USB cable from the laptop
7) Remove the programming dongle from the wheelchair

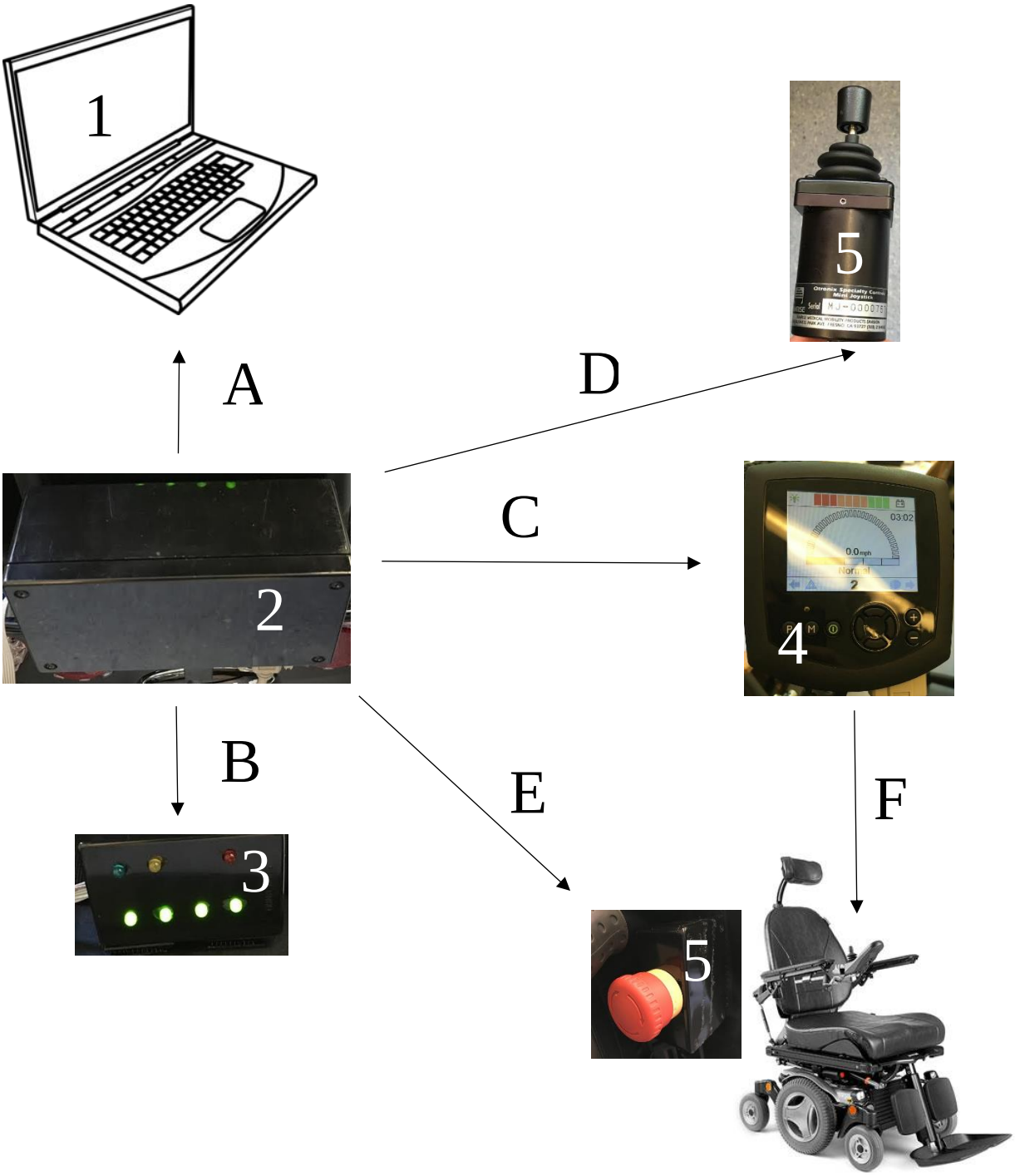
CoPILOT Hardware Set-Up

There are several parts to the CoPILOT Set-Up:

1) Laptop
2) Arduino Control Box
3) LED Box
4) OMNI
5) Joystick
6) Emergency Stop Button

The following scheme shows how each of the items are connected:

Letters A-F correspond to marked cables on the wheelchair.



CoPILOT Software Instructions

Once you have the hardware connected (see previous section), you will need to start the software. The password used throughout the next steps is: lci1234

Starting the System

1) Turn on the laptop and enter the password.

2) Enable Read-Write Access to the Arduino Controller

a. Open a terminal by clicking on the following image in the sidebar

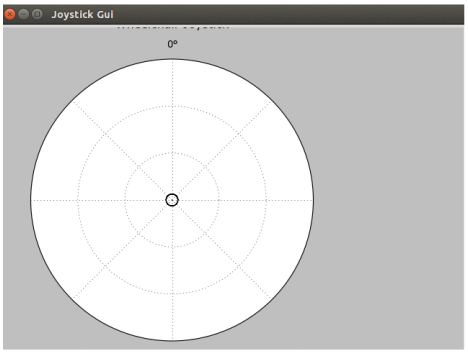
b. When the prompt comes up, type $ sudo chmod a+rw /dev/ttyACM0, and press enter. Enter the password when requested.
   i. Alternatively, you may press the up or down arrow until this appears

3) Connect the wireless remote

a. Open a new terminal by right clicking on the terminal icon, and selecting "New Terminal"
b. When the prompt comes up, type $ sixad –s, and press enter. Follow the prompts and enter the password when requested.
c. When instructed, press the PS button on the joystick to complete the connection.

4) Launch the control application

d. Open a new terminal by right clicking on the terminal icon, and selecting "New Terminal"
e. When the prompt comes up, type $ roslaunch JoyControl JoyControl.launch and press enter. Enter the password when requested
f. The following image should appear:



The wheelchair is now driveable.

5) Record the data

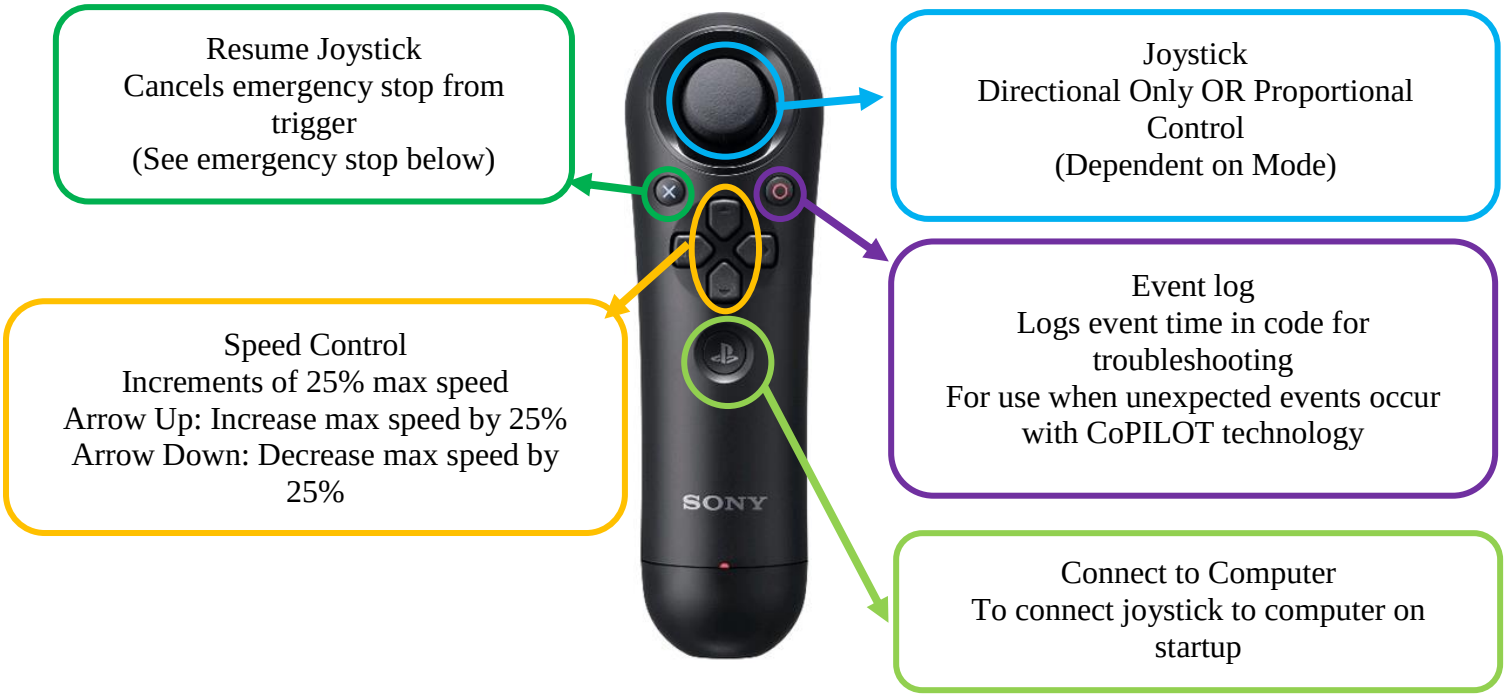
g. This step is optional but will ideally be completed every time the chair is in use as it allows us to log the interaction between the wheelchair and the joystick for analysis should you encounter difficulties.
h. Open a new terminal by right clicking on the terminal icon, and selecting "New Terminal"
i. When the prompt comes up, type $ rosbag record –o trialxx /joy_output /wc_joy /interesting_event and replace xx with a trial number.
j. Trial numbers should be alphanumeric (no spaces or other characters) and ideally will follow the convention ParticipantNumberTrainingSessionNumber. For example, for Participant 04, Training Session 3, you would replace xx with P04T03.

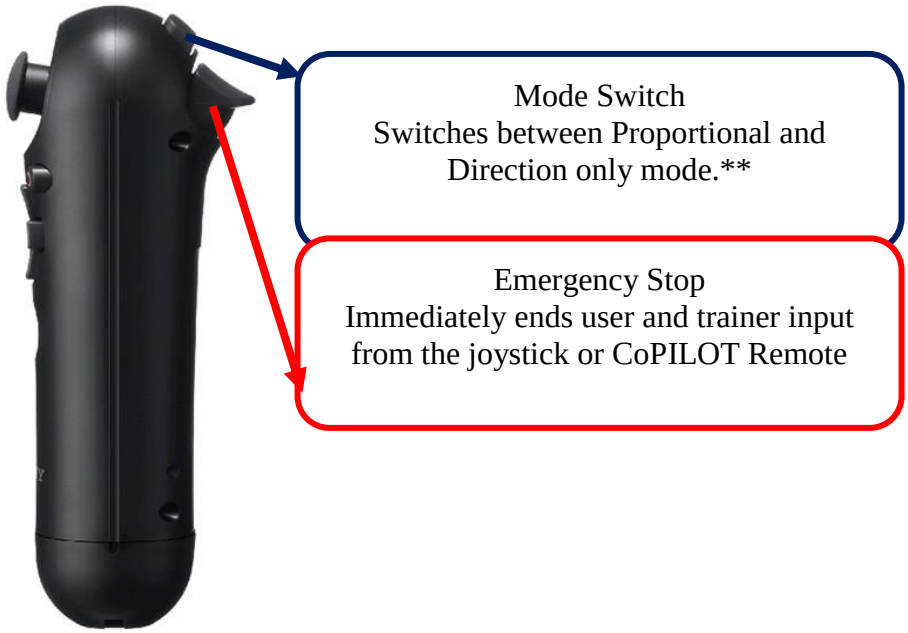
Shutting Down the System

When you have completed your training for the day, you should shut down the system. The following steps may be completed in any order:

1) Close the image that displays the joystick position as seen above.
2) Open the terminal that was used to launch the joystick, and press CTRL+C to disconnect the joystick. Press CTRL+C again to stop the process.
3) Open the terminal that is recording the data and press CTRL+C to stop the thread.
4) Unplug the USB cable that connects the Arduino to the computer and shut down the chair.

CoPILOT Remote Control Mapping





****Modes**

Proportional

Trainer's joystick has both speed and direction control over chair in proportion to displacement of joystick. No input is required on wheelchair user's joystick.

Direction Only

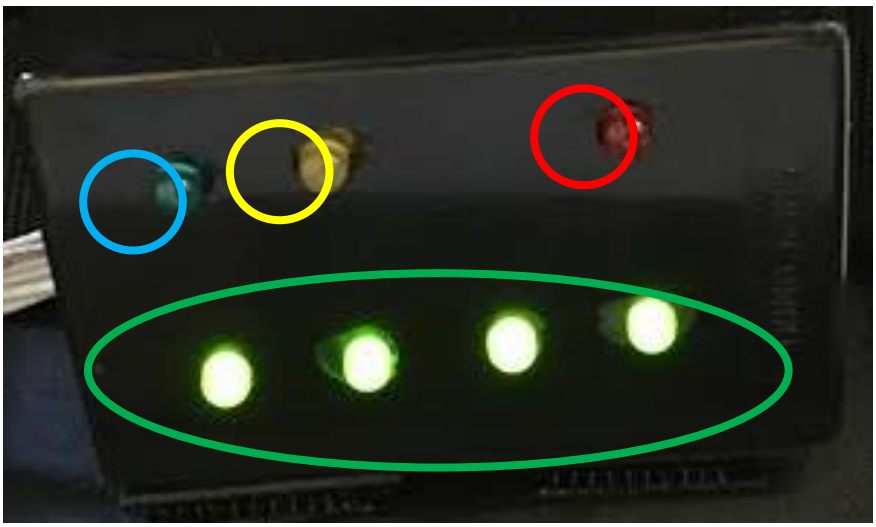
Trainer's joystick has override of direction. Speed is taken from deflection of wheelchair user's joystick. If no input on wheelchair user's joystick, there will be no movement.

LED Interface Mapping

Direction Only Mode

Joystick Disconnected

Emergency Stop Active



Speed Control

4 Green = 100% max speed
3 Green = 75% max speed
2 Green = 50% max speed
1 Green = 25% max speed

Troubleshooting and FAQs

What happens if the joystick or laptop runs out of battery?

If the joystick runs out of battery, the OMNI will produce an SID error, and the chair will automatically stop. To operate the chair, you will need to turn off the chair, and turn back on using the standard r-net joystick. You may then drive your participant to safety and terminate the training session.

What happens if I get too far away from the chair and the joystick disconnects?

If the joystick controller becomes disconnected for any reason, the chair will stop, and the OMNI will produce an SID error which will flash. To clear this error, you will need to reconnect the joystick, turn the OMNI off and back on. Control should resume.

What happens if I need to hit the emergency stop button – what do I do next?

In the event of an emergency where your joystick is not working, you may use the red hard-wired emergency stop button on the chair. If you use this button, the chair will stop, and the OMNI will produce an SID error which will flash. To clear this error, reset the E-stop button by turning it, turn off the OMNI and turn it back on. Control should resume.

I followed all the steps and the joystick isn't working with the chair, what is wrong with it, and how do I fix it?

a. The chair may be plugged in. Unplug the chair from the charger.
b. The joystick may have run out of battery. Charge the joystick.
c. The connections may not be attached correctly. Check all connections.
d. The chair may not be turned on from the OMNI. Turn the chair off and turn on from the power button on the OMNI.
e. If none of the above work, shut the system down and power off the computer. Restart.

I am getting an error code on the OMNI. What do I do?

If you are trying to operate in Standard mode (wheelchair joystick)

a. Ensure you turn on the chair from the wheelchair joystick
b. Press one of the speed buttons on the wheelchair joystick to bring the chair into Profile 7

If you are trying to operate in OMNI mode (CoPILOT joystick)

a. Ensure all cables are plugged in and the CoPILOT system is running on the laptop
b. See troubleshooting for the CoPILOT joystick above

Troubleshooting Tips

-If system is not responding, make sure that the red emergency stop button is pulled out. It tends to get pushed in, which will produce an SID error code.

Appendix I Demographics Form

Participant ID: _____ Rater: _____ Date: _____

Age: _____	Sex: ☐ male (0) ☐female (1)

Marital status:

☐ Married (0) ☐ Single (1) ☐ Separated (2) ☐ Divorced (3) ☐ Common Law (4)
☐ Widowed (5)

Education level (Highest grade or degree completed):

☐ Less than high school (0) What grade level? _____
☐ High school (1) What grade level? _____
☐ Some college (2) Please specify_____
☐ Bachelor's (3) ☐ Masters (4) ☐PhD (5)

Previous driving experience (check all that apply)

☐ None (0)
☐ Bicycle (1)
☐ Motorcycle (2)
☐ Car (3)
☐ Other (4) Type: _____

Primary Diagnosis Requiring Wheelchair:	Secondary diagnoses:

Activities of Daily Living:	Independent (0)	Independent with device (1)	Requires assistance (2)	Current Assistive device:
Ambulation/Mobility	☐	☐	☐	☐ None (0)
Transfers	☐	☐	☐	☐ Cane (1)
Bathing	☐	☐	☐	☐ Walker (2)
Dressing	☐	☐	☐	☐ Wheelchair (3)
Grooming	☐	☐	☐	
Toileting	☐	☐	☐	
Feeding	☐	☐	☐	
Communication	☐	☐	☐	
Access to the community	☐	☐	☐	

Appendix J Outcomes Table

Measure	Construct	Reliability/Validity	T1	T2
Control and Descriptive Measures				
Geriatric Depression Scale – Short Form (GDS)[177]	Mood, depressive symptoms in older adults	Test-retest: r=0.85, exact agreement with clinical diagnosis: 67.5%, presence v. absence of depression:78% [164]	✓	
Functional Comorbidity Index (FCI)[165]	Impact of multiple comorbidities on physical function	Physical component summary correlation to SF-36: -0.47, p<0.01[165]	✓	
Montreal Cognitive Assessment (MoCA)[162]	Cognition/cognitive impairment, dementia	Test-retest: T1-T2 correlation, r=0.92, detected 90% of Mild Cognitive Impairment (MCI), 100% of Alzheimer/Dementia type cognitive impairment[162]	✓	
Primary Clinical Outcome				
Power-mobility Indoor Driving Assessment (PIDA)[103]	Wheelchair Skill Competence and Safety	Intrarater: ICC 0.67, p<0.001 Interrater: ICC 0.87, p<0.001[103]	✓[1]	✓
Secondary Clinical Outcomes				
Wheelchair Skills Test-Questionnaire for PWC Users (WST-Q-P)[101]	Self-Reported Wheelchair Skill Capacity	Inter-rater: ICC 0.72 (95% CI 0.58-0.83)[139]	✓	✓
Wheeling While Talking Test (WheelTalk)[209]	Divided attention while driving	Test-retest: ICC 0.92 Intrarater: ICC 1.00 Interrater: ICC 1.00[209]	✓[1]	✓
Wheelchair Confidence Use Scale for PWC Short Form (WheelCon-P)[167]	Confidence with PWC use	Test-retest: ICC 0.85[210]	✓	✓
Wheelchair Outcome Measure (WhOM)[168]	Wheelchair related goal performance and satisfaction	ICC: 0.77-1.0[168]	✓	✓
Tertiary Clinical Outcomes				
Health Utility Index 3 (HUI3) [170]	Health related quality of life, health utility, cost analysis	Test-retest: Kappa 0.767 Interrater: Kappa >0.8 Intrarater: Kappa 0.29-0.53 Correlation with global utility scores: r=0.59-0.9[170]	✓	✓

[1]Completed at baseline only for participants with previous PWC experience.

Appendix K Participant and Trainer Interview Guides

Wheelchair User

1. Please tell me about your experience learning to drive the powered wheelchair.
    a. What things did you like about it?
    b. What did you not like about it?
2. Which tasks were the easiest to learn?
    a. Why were those the easiest?
3. What things did the training clinician do that made it easier for you to learn to drive the wheelchair?
4. Which tasks were the hardest to learn?
    a. Why did you find those the hardest?
5. What things could the therapist have done to help you learn the skills more easily?
6. How independent do you feel you are now at driving a powered wheelchair?
7. What tasks do you still need assistance for?
8. Please tell me about how safe you felt while learning to drive the powered wheelchair.

Trainers

Please tell me about your experience training the individuals you worked with in this study.

1. Which tasks were easiest to train? Why?
2. Which tasks were most difficult to train? Why?
3. Please describe how you used the CoPILOT system when training throughout the study.
4. How would your training have differed if you did not have the CoPILOT system?
    a. Which tasks would you have trained differently?
5. What were the benefits of the CoPILOT system in your training?
6. What difficulties did you encounter when using the CoPILOT system?
7. Please describe your experience with the visual display.
    a. Which information did you use most frequently?
    b. Which information did you use least frequently?
    c. What information would you add to the visual display, now that you've had a chance to use it with a number of participants?
8. Please describe your experience with the remote control interface.
    a. Which features of the remote control were most easy to use?
    b. Which features of the remote control should we consider changing?
9. How do you think the participant's experience in training differed from those who would have received training according to standard of care?
10. Which individuals would benefit most from the use of CoPILOT for training?
    a. Which characteristics do they have?
    b. Describe the ideal individual who would benefit from the technology.
11. How would you change the CoPILOT system to make it more useful in your day-to-day practice?
12. Please tell me about your experience using the study protocol.
    a. What was successful/challenging in the study protocol?
13. If you were to complete this study again, what changes would you make to the study protocol?

Appendix L Percent Missing Data per Clinical Outcome at T2

Outcome Measure	Missing (n)				% missing total (n=25)
	CoPILOT6 (n=7)	CoPILOT12 (n=6)	WSP6 (n=6)	WSP12 (n=6)	
PIDA	1[1]	0	0	0	4%
WST-Q-P	1[1]	0	0	0	4%
WheelCon-P (Social)	1[1]	0	0	0	4%
WheelCon-P (Mobility)	1[1]	0	0	0	4%
WhOM (Home)	3[1,2,3]	1[3]	1[3]	2[3]	28%
WhOM (Community)	2[1,2]	2[3]	2[3]	1[3]	28%
WheelTalk	6[1,2]	3[2]	1[2]	3[2]	52%
HUI3	2[1,2]	0	0	0	8%

Reasons for Refusal
[1]Participant withdrawal (due to death from influenza n=1)
[2]Participant declined (n=1)
[3]No stated goals

Appendix M Level of Dependence Calculation

Level of assistance required was self-reported by participants across nine activities of daily living: ambulation/mobility, transfers, bathing, dressing, grooming, toileting, feeding, communication, and access to the community. Each activity was scored as:

0	Independent
1	Independent with device
2	Require assistance

Total possible score (require assistance in all nine ADLs) was 18. Individuals who require no assistance receive a score of 0.

Appendix N Consolidated Criteria for Reporting Qualitative Studies (COREQ): 32 Item Checklist

		Chapter Section		
No.	Item.	2	3	4
Domain 1: Research Team and Reflexivity				
Personal Characteristics				
1	Interviewer/facilitator	2.2.1.4	3.2.2	4.2.4
2	Credentials			
3	Occupation			
4	Gender			
5	Experience and Training			
Relationship with the participants				
6	Relationship established	2.2.1.4	3.2.2	4,2,4
7	Participant knowledge of the interviewer			
8	Interviewer characteristics			
Domain 2: Study Design				
Theoretical Framework				
9	Methodological orientation and theory	2.2.1	3.2	4.2
Participant Selection				
10	Sampling	2.2.1.2	2.2.1.1	4.2.3
11	Method of approach			
12	Sample size			
13	Non-participation	N/A	N/A	N/A
Setting				
14	Setting of data collection	2.2.1.4	3.2.2	4.2.4
15	Presence of non-participants	N/A	N/A	N/A
16	Description of sample	2.3.1.1	2.3.1.1	4.3.1
Data Collection				
17	Interview Guide	Appendix A	Appendix A	Appendix E
18	Repeat interviews	2.2.1.4	3.2.2	N/A
19	Audio/visual recording			4.2.4
20	Field notes	2.2.1.6	3.2.4	N/A
21	Duration	2.2.1.4	3.2.2	4.2.4
22	Data Saturation	2.2.1.2	2.2.1.2	4.3.1
23	Transcripts returned	N/A	N/A	N/A
Domain 3: Analysis and Findings				
Data Analysis				
24	Number of data coders	2.2.1.5	3.2.3	4.2.5

		Chapter Section		
No.	Item.	2	3	4
25	Description of the coding tree	N/A	N/A	
26	Derivation of themes	2.2.1.5	3.2.3	
27	Software	2.2.1.5	2.2.1.5	
28	Participant Checking	N/A	3.2.4	4.2.6
Reporting				
29	Quotations presented	2.3.1.2	3.3.2	4,3,4
30	Data and findings consistent			
31	Clarity of major themes			
32	Clarity of minor themes			