

Biomedical Research & Informatics Living Laboratory for Innovative Advances of New Technologies in Community Mobility Rehabilitation: Protocol for a longitudinal evaluation of mobility outcomes

Sara Ahmed, Philippe Archambault, Claudine Auger, Audrey Durand, Joyce Fung,
Eva Kehayia, Anouk Lamontagne, Annette Majnemer, Sylvie Nadeau, Joelle
Pineau, Alain Ptito, Bonnie Swaine

Submitted to: JMIR Research Protocols
on: January 13, 2022

Disclaimer: © The authors. All rights reserved. This is a privileged document currently under peer-review/community review. Authors have provided JMIR Publications with an exclusive license to publish this preprint on its website for review purposes only. While the final peer-reviewed paper may be licensed under a CC BY license on publication, at this stage authors and publisher expressly prohibit redistribution of this draft paper other than for review purposes.

Table of Contents

Original Manuscript..... 4

Supplementary Files..... 19

 Figures 20

 Figure 1..... 21

 Multimedia Appendixes 22

 Multimedia Appendix 0..... 23

 Multimedia Appendix 0..... 23

Biomedical Research & Informatics Living Laboratory for Innovative Advances of New Technologies in Community Mobility Rehabilitation: Protocol for a longitudinal evaluation of mobility outcomes

Sara Ahmed^{1, 2, 3, 4} PhD; Philippe Archambault^{1, 4, 5} PhD; Claudine Auger^{4, 6, 7} PhD; Audrey Durand⁸ PhD; Joyce Fung^{1, 4, 5} PhD; Eva Kehayia^{1, 4, 5} PhD; Anouk Lamontagne^{1, 4, 5} PhD; Annette Majnemer^{1, 3, 4} PhD; Sylvie Nadeau^{4, 6, 7} PhD; Joelle Pineau⁹ PhD; Alain Ptito¹⁰ PhD; Bonnie Swaine^{4, 6, 7} PhD

¹School of Physical and Occupational Therapy, Faculty of Medicine and Health Sciences, McGill University Montreal CA

²Constance Lethbridge Rehabilitation Center, CIUSSS Centre- Ouest de l'île de Montreal, Montreal CA

³McGill University Health Center Research Institute, Center for Outcome Research and Evaluation (CORE) Montreal CA

⁴Centre de recherche interdisciplinaire en réadaptation, CRIR Montreal CA

⁵Jewish Rehabilitation Hospital, CISSS de Laval Laval CA

⁶School of Rehabilitation, Faculty of Medicine, Université de Montréal Montreal CA

⁷Institut universitaire sur la réadaptation en déficience physique de Montréal, CIUSSS du Centre-Sud-de-l'Île-de-Montréal Montreal CA

⁸Computer Science and Software Engineering, Université Laval Quebec city CA

⁹Computer Science, McGill University Montreal CA

¹⁰Department of Neurology and Neurosurgery, Faculty of Medicine, McGill University and McGill University Health Centre Research Institute Montreal CA

Corresponding Author:

Sara Ahmed PhD

School of Physical and Occupational Therapy, Faculty of Medicine and Health Sciences, McGill University

3654 Prom Sir-William-Osler

Montreal

CA

Abstract

The Biomedical Research and Informatics Living Laboratory for Innovative Advances of New Technologies in Community Mobility Rehabilitation (BRILLIANT) program to provide evidence-based research to improve rehabilitation for individuals with Acquired Brain Injury (ABI: traumatic brain injury [TBI], cerebral palsy-fetal/perinatal brain injury, and stroke). The vision of the BRILLIANT program is to optimize mobility of persons with ABI across the lifespan. The program will develop and deploy a comprehensive clinical and community based mobility monitoring system to evaluate the factors that result in poor mobility, and develop personalized mobility interventions that are optimized for specific patient sub-groups. These innovations will be used by front-line clinicians to deliver cost-effective care; the right intervention to the right person at the right time, accounting for long-term functional potential and meaningful participation in the community.

(JMIR Preprints 13/01/2022:12506)

DOI: <https://doi.org/10.2196/preprints.12506>

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**

Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.

Only make the preprint title and abstract visible.

No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**

Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain visible to all users.

Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in http://preprints.jmir.org/preprint/12506

Original Manuscript

Biomedical Research & Informatics Living Laboratory for Innovative Advances of New Technologies in Community Mobility Rehabilitation: Protocol for a longitudinal evaluation of mobility outcomes

S. Ahmed^{1,6,7,10}, P. Archambault^{1,5,10}, C. Auger^{3,4,10}, A. Durand⁸, J.Fung^{1,5,10}, E. Kehayia^{1,5,10}, A. Lamo-ntagne^{1,5,10}, A. Majnemer^{1,7,10}, S. Nadeau^{3,4,10}, J. Pineau⁹, A. Ptito², B. Swaine^{3,4,10}

¹School of Physical and Occupational Therapy, Faculty of Medicine and Health Sciences, McGill University, Montreal, Canada

²Department of Neurology and Neurosurgery, Faculty of Medicine, McGill University and McGill University Health Centre Research Institute

³School of Rehabilitation, Faculty of Medicine, Université de Montréal

⁴Institut universitaire sur la réadaptation en déficience physique de Montréal, CIUSSS du Centre-Sud-de-l'Île-de-Montréal, Montréal, Québec, Canada

⁵Jewish Rehabilitation Hospital, CISSS de Laval, Laval, Quebec, Canada

⁶Constance Lethbridge Rehabilitation Center, CIUSSS Centre- Ouest de l'île de Montreal, Montreal, Canada

⁷McGill University Health Center Research Institute, Center for Outcome Research and Evaluation (CORE), Montreal, Quebec, Canada

⁸Computer Science and Software Engineering, Université Laval, Quebec City, Quebec, Canada

⁹Computer Science, McGill University, Montreal, Canada

¹⁰Centre de recherche interdisciplinaire en réadaptation, CRIR, Montreal, Canada

Corresponding Author:

Sara Ahmed, PhD
School of Physical and Occupational Therapy
McGill University
3654 Prom Sir-William-Osler; Room 45
Montreal, Quebec, Canada
H3G 1Y5
Email: sara.ahmed@mcgill.ca
Tel: 514-487-1891, extension 185

ABSTRACT

The Biomedical Research and Informatics Living Laboratory for Innovative Advances of New Technologies (BRILLIANT) in community mobility rehabilitation to provide evidence-based research to improve rehabilitation for individuals with Acquired Brain Injury (ABI) including traumatic brain injury (TBI), cerebral palsy-fetal/perinatal brain injury, and stroke. The vision of BRILLIANT is to optimize mobility of persons with ABI across the lifespan. The program will develop and deploy a comprehensive clinical and community-based mobility monitoring system to evaluate the factors that result in poor mobility, and develop personalized mobility interventions that are optimized for specific patient sub-groups. These innovations will be used by front-line clinicians to deliver cost-effective care and the right intervention to the right person at the right time, achieving long-term functional potential and meaningful participation in the community.

Keywords: Health Informatics; Individualized Care; Acquired brain injury; Community mobility; Participation; Physical Rehabilitation; Virtual Reality; Artificial Intelligence; Predictive Analytics



INTRODUCTION

Acquired Brain Injury (ABI), including traumatic brain injury (TBI), cerebral palsy-fetal/perinatal brain injury, and stroke, are the leading causes of disability worldwide[1-3]. According to the World Health Organization, the global incidence of all-severity TBI is estimated at 69 million people, while 15 million people suffer a stroke worldwide each year[4-6]. Statistics Canada indicates that 100,000 Canadians will experience a stroke (59%) or a TBI (71%) each year[6]. Many individuals with mild to moderate ABI subsequently return home, yet continue to experience ongoing cognitive and physical impairments, including mobility limitations resulting in restricted participation in meaningful activities at school, leisure, or work. Worldwide, between 1990 and 2019, there has been an 89% and 79% increase in individuals with stroke and TBI, respectively, that require rehabilitation services[7]. Individuals with ABI face challenges once discharged from acute care or rehabilitation and with uncertainty regarding their potential for recovery and regaining independence[8, 9]. Mobility limitations in the community are common and affect 30% of persons with a TBI[10-12], and up to 50% of stroke survivors[13], even after extensive rehabilitation. Long-term follow-up of individuals with ABI show that limitations in mobility appear to undergo little change, even ten years after the initial injury[11, 12].

Mobility is a multidimensional construct and consists of the ability to move oneself independently within a 'life-space', expanding from one's home to the neighbourhood and beyond[14, 15]. Webber's framework identifies five vital interrelated determinants that influence mobility including physical, environmental, cognition, psychosocial, and financial[15] that are also reflected in the International Classification of Functioning, Disability and Health (ICF) framework mobility core set[16]. The built environment also influences community mobility[17, 18]. Guided by the Webber and ICF frameworks, studies have shown that diagnosis alone is not enough to predict mobility limitations and that clinical variables (e.g., length of hospitalization, performance-based measures), intensity of care, patient-reported outcomes of health and social determinants are needed to accurately predict return-to-work potential, work performance, or social integration[17, 18]. Also, social and healthcare decision-makers recognise the importance of modifying features of the social and physical environment to decrease the incidence and severity of disability and enhance mobility and participation[16].

Currently, no reliable measure exists to jointly evaluate the intrinsic and extrinsic factors that influence mobility for individuals with ABI. For the most part, to measure mobility in research, we rely on expensive laboratory technologies and performance-based tools that are burdensome in terms of setup, as well as time needed from highly qualified professionals, clinicians, or research staff for administration and analysis. Importantly, these tools cannot be readily applied in real-life community contexts. Further, electronic platforms that can collect real-time patient- and clinician-reported data are in their infancy, particularly in rehabilitation.

Rapid advances in technologies over the past 10 years enable large-scale biomedical and psychosocial rehabilitation research to improve the function and social integration of persons with physical impairments across the lifespan. In 2017 our team, a network of researchers and clinical partners, established the Biomedical Research and Informatics Living Laboratory for Innovative Advances of New Technologies (**BRILLIANT**) in community mobility rehabilitation to provide evidenced-based research to improve rehabilitation for individuals with **ABI**. **BRILLIANT** builds on the success of the Rehabilitation Living Lab in the Mall ([RehabMaLL](#))[19], a strategic development project and the first transdisciplinary and intersectoral research program to explore the principal obstacles and facilitators (including physical and social) to participation in public environments for persons with disabilities.

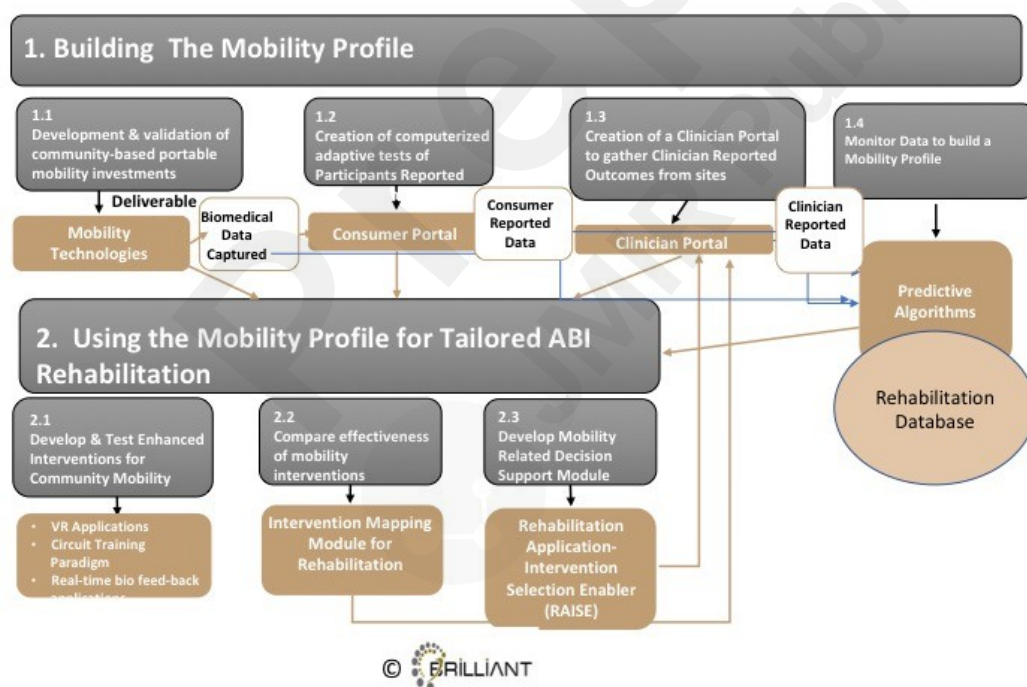
The **vision** of BRILLIANT is to optimize mobility following ABI across the lifespan. The main objectives are to: (1) identify the factors limiting or enhancing mobility in real-world community environments (public spaces including the mall, home, outdoors), and understand their complex

interplay in individuals of all ages with ABI, and (2) customize community environment mobility training by identifying, on a continuous basis, the specific rehabilitation strategies and interventions that patient subgroups benefit from most. Here we present the research and technology plan for the BRILLIANT initiative.

Working towards the vision of BRILLIANT, the deliverables that emerge from the program will be made available to the broader research and public community and health system partners. The continuously growing BRILLIANT database will provide the wider research community with data to conduct evaluative research, in particular comparative effectiveness research, to identify best practices. Community organizations will also be able to access the data to inform their strategic plans for addressing the needs of their members. The digital solutions will be created with health system partners to ensure they can be scaled up and sustained in the clinical programs. The goal is to create a learning rehabilitation system that allows for continuous garnering of data via the technologies that can be shared back with clinicians, patients, and managers to inform clinical decisions.

Here we present the sub-components of the BRILLIANT program, referred to as *Activities* that will allow for a multidimensional evaluation of mobility and the factors that influence mobility (Figure 1). Other sub-components will utilise data generated from the BRILLIANT technologies to evaluate ABI tailored rehabilitation interventions.

Figure 1: BRILLIANT Biomedical and Digital Health Program.



METHODS

Clinical sites and community

A cohort of individuals with ABI (n= 2000, adults and children) will be identified and recruited from the acute care and rehabilitation partner centers within four health regions and followed throughout the continuum of rehabilitation services provided by the health care authorities (listed below). Within these four health regions there are 16 clinical programs that provide intensive post ABI rehabilitation following practice guidelines and in line with other provinces and countries[20-22]. All programs at each center are part of a defined continuum of care for ABI (stroke, TBI, CP). Each of the four health regions is responsible for a specific territory covered by a Centre intégré universitaire de santé et de services sociaux (CIUSSS) or Centre intégré de santé et de services sociaux (CISSS) (otherwise known as the Quebec health authorities). The four sites include the CIUSSS du Centre-Ouest-de-l'Île-de-Montréal (CCOMTL); CIUSSS Lanaudière; CISSS de Laval; CIUSSS Centre-Sud-de-l'Île-de-Montréal (CCSMTL). Participants will also be recruited from the community to be able to address the BRILLIANT objectives among individuals living with ABI, no longer receiving active rehabilitation.

Study population and recruitment

For those recruited in the clinical settings, the sample will consist of patients and their caregiver(s), clinicians, coordinators and managers. A consecutive sample of individuals admitted to acute or rehabilitation care that meet the inclusion criteria will be obtained from admission records. To be eligible to participate 1) patients and/or caregivers must be able to provide informed consent to complete questionnaires and provide access to their provincial health data, and 2) speak and read English or French.

Within each clinical site, the ABI rehabilitation sites' manager will obtain the list of e-mails from clinicians and coordinators interested in participating in the study. A research assistant will obtain consent electronically from clinicians, managers, and patients and caregivers.

Community participants will be recruited through social media and community partner (e.g. Brain Injury Canada) organisations. Interested individuals will be invited to call the study coordinator or complete a form on the BRILLIANT website.

BRILLIANT activities: Biomedical and digital health technologies and data collection

Theme I: Building the Mobility Profile

The objective of theme 1 is to aggregate data from different types of rehabilitation technologies to evaluate the complex interplay between biomedical, personal and environmental factors that explain variability in mobility. This will be the first time this combination of technologies will be used to generate and validate mobility data that combines brain imaging, biomedical, and patient-reported and clinical measures. This will be accomplished by collecting data among the study population that will be followed through the continuum of care (starting in hospital) and into the community (up to 2 years post ABI), enabling us to integrate and analyse their synergistic relationships.

Activity 1.1: *Development and validation of community-based portable mobility instruments*

Moving in community environments is challenging for people with mobility restrictions, as they must adapt to constantly changing contextual/environmental demands (e.g. avoid pedestrians/crowds, adapt to noise-levels and changing terrains, carry loads). Current laboratory and clinically based evaluations of mobility do not sufficiently capture individuals' capacity (can do, controlled conditions) and performance (does in real life) as experienced in the community. We will measure complex visually guided mobility tasks (such as walking and avoiding pedestrians) in community environments, in this case in a shopping mall (Alexis Nihon in Montreal). The mobile technologies we will develop and validate will capture the interaction of patients within the mall environment. Moreover, sensors integrated into assistive technology (e.g. wheelchair seating, walkers and canes) will measure movement, forces and use of devices. Other sensors, installed in the mall environment, such as mall floor, stairs, surfaces, and everyday objects will measure individuals' movement and the use of key areas in the community environment.

We will also use portable EEG to develop metrics, which characterize brain activation patterns in key regions of interest (such as the premotor and motor cortices, and posterior parietal cortex) while patients are performing mobility tasks in the RehabMaLL. The data collected will provide unprecedented sensitivity that is needed to detect and measure biomedical parameters of mobility in the community. Standardized measurements of biomedical outcomes (BiomedO), taken at various stages of the individuals' recovery (acute, rehabilitation and community reintegration phases), will be part of the data used to predict and then classify individuals with ABI into high, medium, or low levels of mobility based on the quality, precision, and coordination of their movement.

At the end of Activity 1.1 we will develop mobility technologies to evaluate personalized longitudinal BiomedO data in a timely manner, a kind of data currently unavailable for individuals with ABI who come to the clinic for follow-up evaluations.

Activity 1.2: *Patient Outcome Reporting Research System: Creating computerized adaptive tests (CATs) of Patient Reported Outcomes (PROs) for mobility-related domains*

Patient reported outcome (PRO) data are crucial for understanding mobility as they enable researchers to measure factors influencing mobility that can only be provided by the individual participants. The greatest challenge to collecting PROs in the laboratory, clinical and community setting, however, is the length of time and repetitiveness of standardised paper-based measures, as well as their lack of precision and sensitivity to change[23]. Computerized adaptive tests (CATs) have emerged as a promising solution to capture PROs more efficiently, in less time, and without jeopardizing the validity and reliability of PRO scores[23]. The PRO, using built-in algorithms, adapts to the participant's ability level by selecting items or a set of items from a large item bank that are sorted from the easiest to the hardest items/questions based on metrics generated from item response theory analyses. The system starts by asking a question of mid-level difficulty (e.g. "Are you able to walk one block" with response options ranging from 1 (unable to do) to 5 (without any difficulty). Depending on the individual's responses to the most recent items administered, the system selects the next item that will bring more precise information (e.g. if the answer to the mid-level items gets a high score, the next item selected has a higher level of difficulty such as "Are you able to run to catch a bus"). The CAT calculates a reliability estimate after each response (e.g. typically 7 to 9 items from a larger item bank of up to 100 items) and stops asking questions when it reaches a predetermined (by research group) reliability estimate. For this reason, it has also been called "tailored testing" that, rather than using a fixed-length questionnaire, only administers items that bring new information. The testing software will include the text of each question as well as extensive information regarding test development and psychometric characteristics (calibration to place items on same scale). The testing application will include item banks and computer adaptive algorithms developed and validated, providing a comprehensive PRO metric of mobility that classifies individuals with ABI across the lifespan and at all levels of mobility. Participants will be

able to complete items using interactive voice recognition systems, smart phones, tablets, or desktop computers; this versatility will maximize user centeredness and can be matched to the setting where the questionnaires are administered. The testing software will also enable researchers to compare the validity and sensitivity to detect change in mobility-related domains of CATs compared to traditional observed measures used in research and in clinical practice. These gold standards will include the Human Activity Profile, which focuses on low level to complex mobility tasks (e.g. turning in bed, walking, running), and the Assessment of Motor and Process Skills, which measures the motor and cognitive process skills of simple to complex community tasks (e.g. retrieving a beverage from the refrigerator, shopping).

At the end of Activity 1.2 we will have developed, with our industry partner the Participant Outcome Reporting Research System, a software application including CATs to measure low to high levels of mobility for persons with ABI.

Activity 1.3 *Clinical Research System to gather Clinician Reported Outcomes (ClinRo) from clinical research sites*

Data captured at the point of rehabilitation care (during episodes of care and as part of research trials) will provide information on performance-based measures of mobility and rehabilitation interventions (physical, psychosocial, and cognitive). We will leverage this work to identify strategies to optimize implementation of the Clinical Research System, including the added value of mobility data for clinicians to identify which interventions are optimal for specific patient sub-groups and to support clinical decision making. Clinical reported outcomes (ClinRo) data obtained using performance-based evaluations of impairment, function, and mobility, as well as data on patient interventions (described in Activity 2.2) will be captured. Later, the system will be built step-by-step using separate modules for each type of data capture source (described in Activity 1.1, 1.2, 1.3) and intervention data source (e.g. split-belt and conventional treadmills, VR, constraint, biofeedback modules described in Activity 2.1) for patients enrolled in trials. Five years into the BRILLIANT research program, when predictive models are developed (after collecting a sufficient amount of data) and validated, the Clinical Research System will include a decision support module (see Activity 2.3) to provide recommendations for selection and implementation of appropriate mobility interventions, tailored to specific ABI characteristics (see Activity 2.2).

This Clinician Reported Outcome (ClinRo) data will be captured using the **Clinical Research System**, to be built using a commercial software package in partnership with an industry partner, allowing researchers and participants to enter data using tablets, smart phones, or computers.

Activity 1.4: *Monitoring data to build the mobility profile*

The BRILLIANT Program will generate and pool biological biomedical data (BiomedO i.e. movement, forces, gaze and neuromuscular data, portable imaging) (Activity 1.1) and PROs data collected using the PRO Research System (Activity 1.2) with Clinician reported (ClinRo) data using the Clinical Research System (Activity 1.3) and brain imaging (BrImagO) data acquired using Magnetic Resonance Imaging (MRI) during the acute, rehabilitation and community reintegration phases. Many of the important underlying causes of aberrant motor performance have signatures that can be measured using MRI. Imaging modalities sensitive to changes in axonal structure, grey matter thickness, functional neurophysiology, neurochemical balance, and microvasculature hold the greatest promise in detecting and characterizing ABI. These imaging modalities have shown great utility for detecting and diagnosing brain damage. Ptito and his team have also successfully used MRI to evaluate brain function (blood oxygenation, flow and volume using fMRI) to characterize mild TBI patients (mTBI), and have also applied this to pediatric populations with Gagnon et al[24]. Importantly, the group is amongst the first to demonstrate the power of fMRI to detect and diagnose mTBI and document recovery. They have also used repetitive Transcranial magnetic stimulation

(rTMS) to increase dorsolateral prefrontal activity and relieve symptom severity in mTBI patients[24]. Imaging can thus be used to zoom in and resolve functional changes in frontal regions, including motor and premotor cortices.

Using individual level data, predictive analytics will be performed to explain variability in mobility. This will enable estimation and validation of predictive models of mobility to assess the independent and joint contribution of explanatory variables allowing us to identify mobility sub-groups. Only with the data from the network of technologies, and experimentation in multiple longitudinal cohorts of persons with ABI of varying levels, and healthy controls of all ages as a comparison, will researchers be able to create such a mobility profile. The combination of the predictive models informed by expert researchers, collaborating industry and clinical partners, and end users will define the rules by which factors are encoded to develop a characteristic mobility profile.

Theme 2: Using the Mobility Profile for Tailored ABI Rehabilitation/Retraining

The objective of this theme is to develop cost-efficient community mobility interventions that optimize outcomes for mobility subgroups of patients with ABI. This will allow us to customize community environment mobility training by identifying, on a continuous basis, specific rehabilitation strategies and interventions that patient subgroups benefit from most.

Activity 2.1: *Developing and testing enhanced interventions for community mobility*

Moving around in community environments requires the skills to cope with multiple simultaneous dimensions (e.g. walking speed and distance, traffic level, sensory cues, postural transitions and cognitive demands). Such skills remain compromised in the majority of individuals with ABI due to non-specific interventions[25, 26]. Best practice guidelines for all age groups recommend the use of task-specific interventions that are individually-tailored, goal-oriented, meaningful, engaging, progressively adapted and of sufficient intensity and duration. As these principles are incorporated into contemporary practice, mobility interventions remain largely focused on training rhythmic/repetitive movements (e.g. treadmill walking, robot-assisted movements, etc.) in clinical laboratory environments. Such practice underestimates the need for: 1) movement adaptation in response to varied, meaningful real-life contexts; 2) co-engagement of motor, sensory, perceptual and cognitive systems and influence of fatigue; and 3) development of problem-solving skills/pre-planned strategies[27] for community mobility. In the context of this activity, we will develop and test individually tailored interventions grounded in best evidence in community ambulation, principles of motor learning and participatory action research with end/knowledge-users.

Specifically, for patients who are in the intensive rehabilitation phase (i.e. first 3 months of rehabilitation and pre-discharge to home/community), enhanced practice of community mobility skills (walking and wheeling) will be provided through virtual reality (VR) applications comprising of mobility tasks and environments of increasing complexity (e.g. from unobstructed single task walking a short distance to walking 100m in a crowded mall while remembering shopping items). These VR applications will be developed collaboratively with knowledge users (patients of various ages and clinicians) as well as key industrial partners specialized in video game development and VR applications for the clinical setting. For patients with ABI in the community re-integration phase (post-discharge from intensive rehab), mobility interventions taking place within the community will be co-developed and subsequently tested, in collaboration with Cominar (owner of Alexis Nihon and partner in the RehabMaLL), and other community partners (e.g. ALTERGO, <https://www.altergo.ca>). We will implement circuit training for mobility within the rehabilitation setting to develop and test a circuit training paradigm involving complex community mobility skills in a community environment (e.g. the mall). Using wearable sensor technology, we will further develop real-time biofeedback applications to provide 'on-line' knowledge of performance on movement strategies (e.g. lower limb

movement and weight bearing symmetry), instantaneous walking and propulsion speed and distance while patients move about in community environments.

Activity 2.2 *Comparative effectiveness of mobility*

Recent research suggests that accounting for the time spent in *specific* physical and occupational therapy activities (intervention-level data), above and beyond patients' characteristics (patient-level data), has the potential to enhance the predictive value of models explaining rehabilitation outcomes after ABI[28]. Capturing accurate and comprehensive intervention-level data (also a ClinRo) at different times within the continuum of care (e.g. acute care and then transitioning to inpatient and outpatient rehabilitation and community re-integration) allows us to identify the mediating effects of specific rehabilitation interventions to the recovery of mobility in different patient subgroups. This electronic intervention data capture application will involve validation of intervention parameters within the Canadian context (and for children/youth), and follow the most recent international reporting guidelines for interventions (e.g. TIDieR checklist)[29] to create an ABI-specific treatment classification in a research-based therapeutic coding system (with a focus on mobility). This mapping application will allow adding specific treatment variables and refining the predictive power of the models to guide decision support (Activity 2.3). We will compare how the intervention mapping applies to VR, gait retraining (e.g. gait circuits in a gym, split belt treadmill, treadmill propulsion), and community-based interventions for mobility and extend to persons with ABI.

We will build on this work to create the Intervention Mapping Module for Rehabilitation in the Clinical Research System (Activity 1.3) to capture intervention parameters mentioned above and strategies used by therapists when teaching indoor/outdoor community mobility skills.

Activity 2.3: *Mobility decision support development*

In this activity we will develop and evaluate the impact of a decision support module, Rehabilitation Application – Referral and Intervention Selection Enabler (RAISE), on clinician and patient clinical decision making in terms of mobility and practices. Using the predictive models developed in Activity 1.3 and the analysis of intervention factors developed in Activity 2.2, we will build RAISE for clinicians and conduct the first-ever implementation studies and randomized trials on the acceptability and effectiveness of RAISE for referral and discharge across transitions in care and selection of mobility retraining strategies. Since length of stay in intensive rehabilitation is shortening, therapists have to assign optimal community-based rehabilitation strategies early on in the treatment plan.

A second challenge arises when transitioning from acute care to home, when families and patients need a clear understanding of the mobility prognosis to make decisions about discharge planning resources and alterations to their home environment. The RAISE will also be able to identify the best responses to questions posed by clinicians using plain language. For example, clinicians will be able to enter a question regarding the mobility prognosis such as “when will patient X be able to climb 12 steps independently based on his present profile?” or “will patient X be able to walk in a shopping mall independently at 6 months?” or “would protocol A or B work best for this patient?” The RAISE and natural language applications will leverage the data collected in Theme 1 and the analysis from Activities 2.1 and 2.2 to inform the intervention plan and answer these types of questions.

The RAISE as an add on within the Clinical Research System (Activity 1.3) will be designed to allow clinicians to produce personalized intervention plans for subgroups of patients based on their mobility profile using data-driven methods.

RESULTS

The biomedical infrastructure and equipment have been established across the research labs and

clinical sites. The participating reporting outcome system contains CAT PROMs including Patient Reported Outcomes Measurement Information System (PROMIS)[30] and Assistive Technology Outcome Profile for Mobility (ATOP)[30, 31] and development of other modules to feedback PROM and mobility outcomes to participants are ongoing[32-34]. The development of the clinical information system is ongoing. Ethics approval for each activity is ongoing. Recruitment is expected to begin in February 2022.

KNOWLEDGE MOBILIZATION PROCESS WITH PARTNERS AND END-USERS

In addition to traditional knowledge dissemination (publications in scholarly journals and conferences), the BRILLIANT team will undertake yearly interactive knowledge mobilization sessions with health system and community partners and end-users. These sessions will include, but are not limited to, dedicated work sessions with informatics specialists, patient-representatives from a range of sub-populations, clinicians, and the provincial health ministry (MSSS).

To ensure that experiential knowledge is effectively exchanged within the research community, the team will offer 1-day specialized training sessions. This intensive course will be directed at training clinicians, trainees, and highly qualified professionals, on the use of the Clinical Research System, including the RAISE decision support system, and offered in person and virtually. Because such a commitment can be difficult for many clinicians, the BRILLIANT program will hold 4 half-day training sessions annually at clinical sites to be close to clinical programs and activities.

The mobility technologies and decision supports that identify optimal mobility interventions will have important repercussions for changes to clinical guidelines and practices. The BRILLIANT knowledge mobilization plan will also inform policies of the Quebec Health Care System, and insurance compensation of victims of automotive accidents (e.g., SAAQ), workplace accidents, and violent crimes. We will further communicate our results to rehabilitation policy planners across the province and nationally to inform program planning for individuals with ABI, from rehabilitation-based interventions to community planning to support ongoing monitoring and mobility retraining support in the community. Linkages with the national and international Brain Injury, health professional, and accreditation associations will help to disseminate the results to persons with a vested interest in improving the lives of individuals with ABI.

Over time, through international collaborations, BRILLIANT will build partnerships to adapt and disseminate BRILLIANT innovations to other research networks and clinical settings. This work has started via the Virtual Health and Wellbeing Living Lab Infrastructure (VITALISE) initiative that brings together three European Living Labs and BRILLIANT to share resources and expertise in technology development for rehabilitation, transitions in care, and smart living environments[35-37].

Once tested and validated, we will explore commercialisation opportunities with our industry partners. We will aim to make the Participant Reporting System, Clinical Research System, and RAISE readily available through an open source framework for other investigators to keep building and deploying RAISE, and health networks to deploy within their clinical programs.

DISCUSSION

The BRILLIANT digital health and biomedical technologies will enable users to conduct research along the two main themes of BRILLIANT: to collect the necessary data allowing the creation of a mobility profile for patients with ABI in community environments; and to make use of the mobility profile for customized rehabilitation and retraining programs. The BRILLIANT research innovations will result in technology development with industry, evidence-based practices by clinical end users,

and changes to clinical and governmental guidance, designed to positively impact ABI clinical outcomes.

In summary the Breakthroughs and Outcomes of Benefit to Rehabilitation Care from BRILLIANT include:

Community-Based Tracking of Mobility: Thousands of ABI patients admitted annually to acute care and rehabilitation centers will see their lives improved by having a means to monitor limitations in mobility once they leave the care setting. Indeed, for children and adults who return home from acute rehabilitation, there has been limited measurement of their functioning in their own community. The community-based tracking deliverable will enable our practice teams, including physicians in the community who do not usually have access to information on functioning, to measure the mobility limitations that persons with ABI experience in their environments. Ultimately, the benefits are that patients will be able to return to their home environment sooner with greater mobility and function.

ABI Mobility Limitations, Interventions, and Comparative Effectiveness Research: A Patient Research System to efficiently and precisely evaluate patient-reported outcome (PRO) domains that influence mobility, and a Clinical Research System (CRS) will allow for data capture at the point of care. the CRS will include a much-needed taxonomy of rehabilitation interventions. As there is currently no rehabilitation electronic health record in the participating sites, there are no mechanisms to capture this data, limiting a clinician's ability to evaluate patient progress, and for researchers and health administrators, to identify the care patients receive in rehabilitation. The CRS will be one of the first-ever rehabilitation electronic records.

A Predictive Model to Explain Variability in Mobility: BRILLIANT data collected will allow us to continuously develop and validate predictive algorithms to explain variability in mobility. This will further enable estimation and validation of predictive models of mobility to assess the independent and joint contribution of explanatory variables allowing us to identify mobility sub-groups. For clinicians, this provides a means to identify which factors to focus on in rehabilitation mobility retraining, using a personalized approach (tailored to context) rather than the current prescriptive or recipe approach.

Customized rehabilitation/retraining programs: The decision support tool will utilize the predictive models to build a mobility decision support, RAISE. Currently patients receive relatively the same rehabilitation mobility training interventions that often do not target the specific factors limiting a given individuals' mobility. For patients, this means receiving interventions that address their specific needs is likely to optimise their outcome following rehabilitation. This provides clinicians a means of distinguishing the mobility levels of patients and the interventions that are most likely to be effective.

BRILLIANT represents the first large-scale use of biomedical community-based technology and health informatics to support a person-centered (personalized) approach to measuring function over time and developing interventions to improve community-based mobility. We expect the innovations created to accelerate research and discovery in ABI research and deliver the information needed for clinicians to be able to deliver cost-effective care that includes *the right intervention to the right person at the right time*, while achieving long-term functional potential and meaningful participation in the community.

Acknowledgements:

The BRILLIANT Program is funded by the Canadian Foundation of Innovation (#36053) and the Initiatives for the Development of New Technologies and Innovative Practices in Rehabilitation – INSPIRE.

Conflicts of Interest: There are no conflict of interest to report

Multimedia Appendix of supplementary files: Reviewers comments for the grant proposal

References:

1. Maas AI, Stocchetti N, Bullock R. Moderate and severe traumatic brain injury in adults. *The Lancet Neurology*. 2008;7(8):728-41.
2. Patil M, Gupta A, Khanna M, Taly AB, Soni A, Kumar JK, et al. Cognitive and Functional Outcomes following Inpatient Rehabilitation in Patients with Acquired Brain Injury: A Prospective Follow-up Study. *J Neurosci Rural Pract*. 2017;8(3):357-63.
3. Prabhakaran V. Non-communicable diseases in India: Transitions, burden of disease and risk factors-A short story. *India health beat*. 2012;6(1).
4. Dewan MC, Rattani A, Hung YC, Punchak M, Shrime MG, Park KB, et al. Estimating the global incidence of traumatic brain injury. *Journal of Neurosurgery*. 2019;130(4):1080-97.
5. Thrift AG, Thayabaranathan T, Howard G, Howard VJ, Rothwell PM, Feigin VL, et al. Global stroke statistics. *Int J Stroke*. 2017;12(1):13-32.
6. Chambers-Richards TLA. Risk factors, trends, health care and general life satisfaction for select neurological conditions among an aging population in Canada.: University of Saskatchewan; 2020.
7. Cieza A, Causey K, Kamenov K, Hanson SW, Chatterji S, Vos T. Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet*. 2021;396(10267):2006-17.
8. Ihasani R, Ferreira TJ, Valois M-F, Alghamdi S, Singh D, Ahmed S. Enrollment and dropout rates of individuals with chronic obstructive pulmonary disease approached in telehealth interventions: A systematic review and meta-analysis. . Submitted to *Chest Journal* on March 8, 2021.
9. Borgen IMH, Røe C, Brunborg C, Tenovuo O, Azouvi P, Dawes H, et al. Care transitions in the first 6 months following traumatic brain injury: Lessons from the CENTER-TBI study. *Ann Phys Rehabil Med*. 2021;64(6):101458.
10. McNair ND. The Projected Transition Trajectory for Survivors and Carers of Patients Who Have Had a Stroke. *Nurs Clin North Am*. 2019;54(3):399-408.
11. Oyesanya TO, Loflin C, Harris G, Bettger JP. "Just tell me in a simple way": A qualitative study on opportunities to improve the transition from acute hospital care to home from the perspectives of patients with traumatic brain injury, families, and providers. *Clin Rehabil*. 2021;35(7):1056-72.
12. Ross SY, Roberts S, Taggart H, Patronas C. Stroke Transitions of Care. *Medsurg Nurs*. 2017;26(2):119-23.
13. Heart and Stroke Foundation. Pratiques optimales de l'AVC au Canada. Recommandation Canadiennes pour les pratiques optimales de soins de l'AVC. Réadaptation, rétablissement et participation communautaire après un AVC Deuxième partie : Les transitions et la participation communautaire après un AVC 2019. p. 1-82.
14. Tsai L-T. Walking, physical activity and life-space mobility among older people. *Studies in sport, physical education and health*. 2017(254).
15. Webber SC, Porter MM, Menec VH. Mobility in older adults: a comprehensive framework. *Gerontologist*. 2010;50(4):443-50.
16. World Health Organization. International classification of functioning, disability and health: ICF: Geneva. 2001.
17. Clarke P, Ailshire JA, Bader M, Morenoff JD, House JS. Mobility disability and the urban built environment. *Am J Epidemiol*. 2008;168(5):506-13.
18. Nagel CL, Carlson NE, Bosworth M, Michael YL. The relation between neighborhood built environment and walking activity among older adults. *Am J Epidemiol*. 2008;168(4):461-8.
19. Ahmed S, Swaine B, Milot M, Gaudet C, Poldma T, Bartlett G, et al. Creating an inclusive

mall environment with the PRECEDE-PROCEED model: a living lab case study. *Disability and Rehabilitation*. 2017;39(21):2198-206.

20. Publications du ministère de la Santé et des Services sociaux "MSSS". Trousse d'outils cliniques pour l'évaluation des personnes ayant subi un accident vasculaire cérébral (AVC) - Phases hyperaiguë et aiguë de l'AVC 2019 [Available from: https://publications.msss.gouv.qc.ca/msss/document-002419/?&txt=personne&msss_valpub&date=DESC].

21. Institut national d'excellence en santé et en services sociaux "INESSS". Modes d'organisation des services de soins intensifs: état de connaissances et indicateurs de qualité 2018 [Available from: <https://www.inesss.qc.ca/en/publications/publications/publication/modes-dorganisation-des-services-de-soins-intensifs-etat-de-connaissances-et-indicateurs-de-qualite.html>].

22. Canadian stroke best practices "Csbp". Overview, Methods and Knowledge Exchange 2019-2021 [Available from: <https://www.strokebestpractices.ca/recommendations/overview-methods-and-knowledge-exchange>].

23. Lai JS, Cella D, Choi S, Junghaenel DU, Christodoulou C, Gershon R, et al. How item banks and their application can influence measurement practice in rehabilitation medicine: a PROMIS fatigue item bank example. *Arch Phys Med Rehabil*. 2011;92(10 Suppl):S20-7.

24. Koski L, Kolivakis T, Yu C, Chen J-K, Delaney S, Ptito A. Noninvasive brain stimulation for persistent postconcussion symptoms in mild traumatic brain injury. *Journal of neurotrauma*. 2015;32(1):38-44.

25. Richards CL, Malouin F, Nadeau S. Stroke rehabilitation: clinical picture, assessment, and therapeutic challenge. *Prog Brain Res*. 2015;218:253-80.

26. Dancause N, Nadeau S, Rossignol S. Preface. Sensorimotor rehabilitation at the crossroads of basic and clinical sciences. *Prog Brain Res*. 2015;218:xix-xx.

27. Barclay R, Ripat J, Mayo N. Factors describing community ambulation after stroke: a mixed-methods study. *Clinical rehabilitation*. 2015;29(5):509-21.

28. Dijkers MP, Hart T, Tsaousides T, Whyte J, Zanca JM. Treatment taxonomy for rehabilitation: past, present, and prospects. *Arch Phys Med Rehabil*. 2014;95(1 Suppl):S6-16.

29. Hoffmann TC, Glasziou PP, Boutron I, Milne R, Perera R, Moher D, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *Bmj*. 2014;348.

30. Cella D, Yount S, Rothrock N, Gershon R, Cook K, Reeve B, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS): progress of an NIH Roadmap cooperative group during its first two years. *MedCare*. 2007;45(5 Suppl 1):S3-S11.

31. Auger C, Rushton PW, Jutai JW, Miller WC. Reliability, convergent validity and applicability of the Assistive Technology Outcome Profile for Mobility for middle-aged and older power wheelchair users. *Australian occupational therapy journal*. 2018;65(5):439-48.

32. Alhasani R, Godbout, M., Durand, A., Auger, C., Lamontagne, A., Ahmed, S. . . Informing the Development of a Core Outcome Set of Mobility among Individuals with Acquired Brain Injury using Natural Language Processing. *BMC Neurology*. Submitted March 17, 2021.

33. Alhasani R, Auger, C., de Paiva Azevedo, M., Ahmed, S. . Quality of Mobility Measures among Individuals with Acquired Brain Injury: An Umbrella Review. *Quality of Life Research Journal*. Submitted on January 22, 2021.

34. Alhasani R, Radman D, Auger C, Lamontagne A, Ahmed S. Clinicians and individuals with acquired brain injury perspectives about factors that influence mobility: creating a core set of mobility domains among individuals with acquired brain injury. *Annals of medicine*. 2021;53(1):2365-79.

35. Santonen T, Petsani D, Julin M, Garschall M, Kropf J, Van der Auwera V, et al. Co-creating

harmonized living lab for big data driven hybrid personas development: Protocol for co-creating, testing and seeking consensus (Preprint)2021.

36. Petsani D, Ahmed S, Petronikolou V, Kehayia E, Alastalo M, Santonen T, et al. Digital Biomarkers for supporting transitional care decisions: Protocol for a transnational feasibility study (Preprint)2021.

37. Bernaerts S, Witte N, Van der Auwera V, Bonroy B, Muraru L, Bamidis P, et al. Rehabilitation supported by technology: Protocol for an international co-creation and user experience study (Preprint)2021.

Abbreviations:

Acquired Brain Injury (ABI)

Assistive Technology Outcome Profile for Mobility (ATOP)

Biomedical Research and Informatics Living Laboratory for Innovative Advances of New Technologies in Community Mobility Rehabilitation (BRILLIANT)

Brain imaging (BrImagO)

Centre intégré de santé et de services sociaux (CISSS)

Centre intégré universitaire de santé et de services sociaux (CIUSSS)

CIUSSS Centre-Sud-de-l'Île-de-Montréal (CCSMTL)

CIUSSS du Centre-Ouest-de-l'Île-de-Montréal (CCOMTL)

CIUSSS Lanaudière; CISSS de Laval

Clinical Research System (CRS)

Clinician Reported Outcomes (ClinRo)

Computerized adaptive tests (CATs)

Magnetic Resonance Imaging (MRI)

Mild TBI patients (mTBI)

Ministry of Health (MSSS)

Participant Reported Outcomes (PROs)

Patient Reported Outcomes Measurement Information System (PROMIS)

Patient Research System (PRO)

Referral and Intervention Selection Enabler (RAISE)

Rehabilitation Living Lab in the Mall ([RehabMaLL](#))

Repetitive Transcranial magnetic stimulation (rTMS)

Traumatic brain injury (TBI)

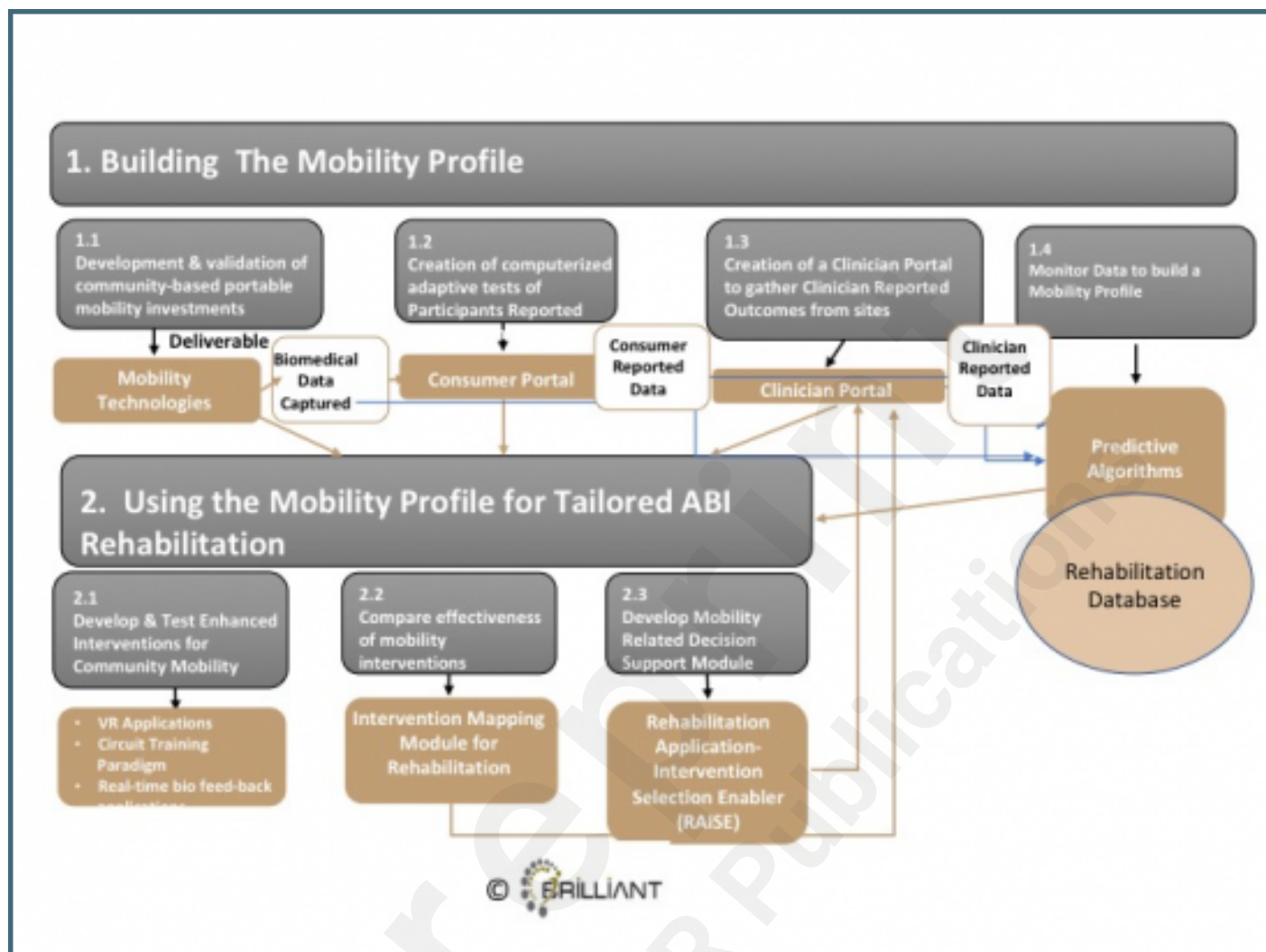
Virtual Health and Wellbeing Living Lab Infrastructure (VITALISE)

Virtual reality (VR)

Supplementary Files

Figures

BRILLIANT Biomedical and Digital Health Program.



Multimedia Appendixes

Untitled.

URL: <http://asset.jmir.pub/assets/6cb290ce95ba12ccf982886b16fdc1f8.pdf>

Untitled.

URL: <http://asset.jmir.pub/assets/58657f3a977a4ae5d5e69cd7b4552ceb.pdf>

