

Socioeconomic benefits of funding for university research in Quebec's Estrie region

Final report

PREPARED FOR:



Canada Foundation for Innovation (CFI)

Fonds de recherche du Québec (FRQ)

Ministère de l'Économie et de l'Innovation (MEI)

PREPARED BY:



GOSS GILROY INC.

Management Consultants
Conseillers en gestion

Goss Gilroy Inc. (GGI)

DATE:

May 5, 2021

Table of Contents

Acronyms	2
Overview	3
1.0 Introduction	5
2.0 Overview of research projects.....	10
2.1 Smart homes.....	10
2.2 Telerehabilitation: TeraPlus telehealth platform project.....	11
2.3 Actigraphy and kinematics of movement	12
2.4 Physical exercise during hemodialysis	13
2.5 Neurostimulation therapy.....	14
2.6 Non-pharmacological nutritional strategies for cognitive impairment	15
2.7 Geriatric nutrition	16
2.8 Living laboratory and mobility: The Mobilaînés project.....	16
3.0 Project outcomes	18
3.1 Outcomes in academic settings	18
3.2 Socioeconomic impacts.....	22
4.0 Summary and conclusion	29
Appendix A: Funding of cases	31

Acronyms

3IT: Interdisciplinary Institute for Technological Innovation

AD: Alzheimer's disease

CdRV: Centre de recherche sur le vieillissement [Research centre on aging]

CFI: Canadian Foundation for Innovation

CHSLD: Residential and long-term care centre

CHUS: Centre hospitalier universitaire de Sherbrooke [Sherbrooke university hospital centre]

CIHR: Canadian Institutes of Health Research

CIUSSS: Integrated University Health and Social Services Centre

CKD: Chronic kidney disease

ESTRAD: Équipe spécialisée en téléreadaptation à domicile [Team specialized in home-based telerehabilitation]

FRQ: Fonds de recherche du Québec [Quebec Research Funds]

FRQNT: Fonds de recherche du Québec – Nature et technologies [Nature and technologies]

FRQS: Fonds de recherche du Québec – Santé [Health]

HQP: Highly qualified personnel

INTER: Interactive technologies of engineering in rehabilitation

kMCT: Ketogenic medium chain triglyceride

LIPPA: Laboratoire d'innovations par et pour les aînés [Laboratory of innovations by and for seniors]

LTCH: Long-term care home

MCI: Mild cognitive impairment

MEI: Ministère de l'Économie et de l'Innovation (Québec) [Ministry of the economy and innovation]

NAM: Nutrition as Medication

NSERC: Natural Sciences and Engineering Research Council of Canada

ONS: oral nutritional supplements

Overview

The aim of this study is to document the socioeconomic impacts of research projects on aging and rehabilitation that have been funded by the Canada Foundation for Innovation (CFI), the Ministère de l'Économie et de l'Innovation (MEI) and the Fonds de recherche du Québec (FRQ). More specifically, it will document the impacts of selected research projects carried out by the Centre de recherche sur le vieillissement [Research centre on aging] of the Estrie integrated university health and social services centre (CIUSSS de l'Estrie) and the interactive technologies of engineering in rehabilitation (INTER) group, and will show the degree to which various funding programs are complementary and in synergy. This study has been conducted using the following eight research projects as case studies:

- Smart homes
- Telerehabilitation: TeraPlus telehealth platform project
- Actigraphy and kinematics of movement
- Physical exercise during hemodialysis
- Neurostimulation therapy
- Non-pharmacological nutritional strategies for cognitive impairment
- Geriatric nutrition
- Living laboratory and mobility: The Mobilaînés project

The study's findings are based on a documentation review and a semi-directed interview campaign.

Results

The results show that funding has had significant repercussions at the university level. FRQ, MEI and CFI funding provided foundational infrastructure, including through equipment and software purchases that allowed researchers to build multidisciplinary teams with the knowledge and skills needed for their projects. In many cases, these initial funding sources had leverage effects that enabled researchers to obtain other funding. Researchers' work and funding also benefited multiple generations of students. Participating in these projects helped them get educational funding and/or knowledge of a given specialized field. After completing their studies, many students took positions in the health field or in academia.

Moving beyond the academic setting, these projects also had significant benefits for the users and institutions involved. Our study found that they helped to improve seniors' health and well-being by improving their diet, medication use, care, access to care and services and autonomy. Although some projects are still in development, they are already helping to improve seniors' quality of life and, in some cases, helping them to continue living at home. Some projects, by their nature, have also benefited younger populations who face issues similar to those faced by seniors.

The projects have also had an impact on some institutions and organizations located in Estrie. In addition to improving their services for seniors, the projects have helped to increase various partner organizations' awareness of certain issues that seniors face and the organizations' familiarity with local agents of change, as well as to connect partner organizations who had no relationship prior to the project. Many projects also had economic impacts, although that was not always the intention. We observed a better use of professionals' time, savings connected to longer independent living, prevention of health costs (medications and care) and increased or maintained income for users and organizations. Since these projects are still in their early stages, it is highly probable that these impacts will grow over the years to come.

* * *

1.0 Introduction

The Ministère de l'Économie et de l'Innovation (MEI) and the Fonds de recherche du Québec (FRQ) are organizations working to support the development of research and science throughout Quebec. The MEI develops and administers a variety of financial assistance programs and tax measures to help companies and research organizations continue or expand their work. The FRQ's funds (Nature and technologies, Society and Culture and Health) support research along four program axes: training the next generation of researchers, careers in research and promotion, research projects and research groups. The Canada Foundation for Innovation (CFI) provides funding to Canada's universities, colleges, hospitals and non-profit research organizations so that researchers can obtain the research infrastructure they need to innovate in order to create stronger communities.

As an outgrowth of their common interest in showcasing the impacts of their investments, the CFI, the MEI and the FRQ decided to join forces to study the impacts of their shared and complementary investments in a geographical region. After consultation and preliminary research, they selected the Estrie region. They discussed a number of potentially promising themes for their examination of impacts beyond the postsecondary academic setting, before selecting the theme of aging and rehabilitation in order to document the results and complementary nature of FRQ, CFI and MEI investments.

The importance of this field of research, whose pre-existing issues were exacerbated by the SARS-CoV-2 pandemic, is accentuated by the demographic context. The demographic weight of seniors in Quebec is currently 20.5% (2021) and continually growing: the percentage of people 65 and older who are part of the active population grew from 4.7% in 2010 to 7.3% in 2019.^{1, 2} According to the most recent projections, in 2041, 26.3% of the Quebec population will be aged 65 and older.³ In Estrie, the percentage will rise from 21% to 30% between 2016 and 2041.⁴

About the Centre de recherche sur le vieillissement of the CIUSSS de l'Estrie and the INTER group

Founded in 1988, the Centre de recherche sur le vieillissement (CdRV) is one of Canada's most prominent research centres specializing in aging. The CdRV is part of the CIUSSS de l'Estrie - CHUS [Sherbrooke university hospital centre] and is affiliated with the Université de Sherbrooke. For over 20 years, it has been funded by the FRQ – Santé (FRQS) as part of its Centres et instituts de recherche [research centres and institutions] program. CdRV members conduct research aimed at producing knowledge and incorporating it into processes that support healthy aging and encourage society to adapt to this complex issue. CdRV research helps to prevent, slow and improve the aging process and maintain seniors' independence.

¹ <https://www.inspq.qc.ca/le-vieillissement-au-quebec> (in French)

² <https://bdso.gouv.qc.ca/docs-ken/vitrine/vieillissement/index.html?theme=travail&tab=1> (in French)

³ <https://publications.msss.gouv.qc.ca/msss/fichiers/ainee/aines-quebec-chiffres.pdf> (in French)

⁴ <https://statistique.quebec.ca/fr/fichier/perspectives-demographiques-du-quebec-et-des-regions-2016-2066-edition-2019.pdf> (in French)

A number of CdRV rehabilitation researchers are also part of the INTER (Interactive technologies of engineering in rehabilitation) group, a strategic inter-institutional group that since 2011 has been funded by FRQ Nature and technologies (FRQNT). The research projects of INTER, which rely in particular on the infrastructures of Interdisciplinary Institute for Technological Innovation (3IT) and Laboratoire DOMUS at Université de Sherbrooke, are centered around two key intervention areas: a) smart homes (e.g., home assistance, telehomecare, home automation) and b) mobility (e.g., smart wheelchairs, exoskeletons, prostheses/orthoses, geospatial technology). The research of the CdRV and the INTER group are complementary, enabling researchers to address clinical needs by developing technological solutions rooted in engineering. Researchers at the CdRV are working with various stakeholders in the Estrie health network on a variety of applied research projects in telerehabilitation, nutrition and physical activity, pain management, personal mobility, computer science, robotics and home automation.

Between 2010 and 2020, the FRQ awarded over \$25 million to post-secondary institutions in Estrie for research on aging. The projects funded addressed the issue in terms of its health aspects (biological, clinical, population-based) and its technological, social and societal aspects (economy and jobs, design of residential settings, services). The CFI, meanwhile, awarded over \$6 million to post-secondary institutions in Estrie for the acquisition of research infrastructure related to aging and rehabilitation. As the CFI generally funds 40% of projects, this points to total investments of around \$15 million. Overall, the CFI invested in 28 projects funded between 1998 and 2020 and led by 25 separate members of the CdRV or INTER. Lastly, the MEI provided matching funds for the CFI's contributions (\$6 million) and contributed around \$11 million for the construction of the 3IT at Université de Sherbrooke and for studying smart homes.

1.1 Objectives and methodological approach

The primary objectives of this study are to:

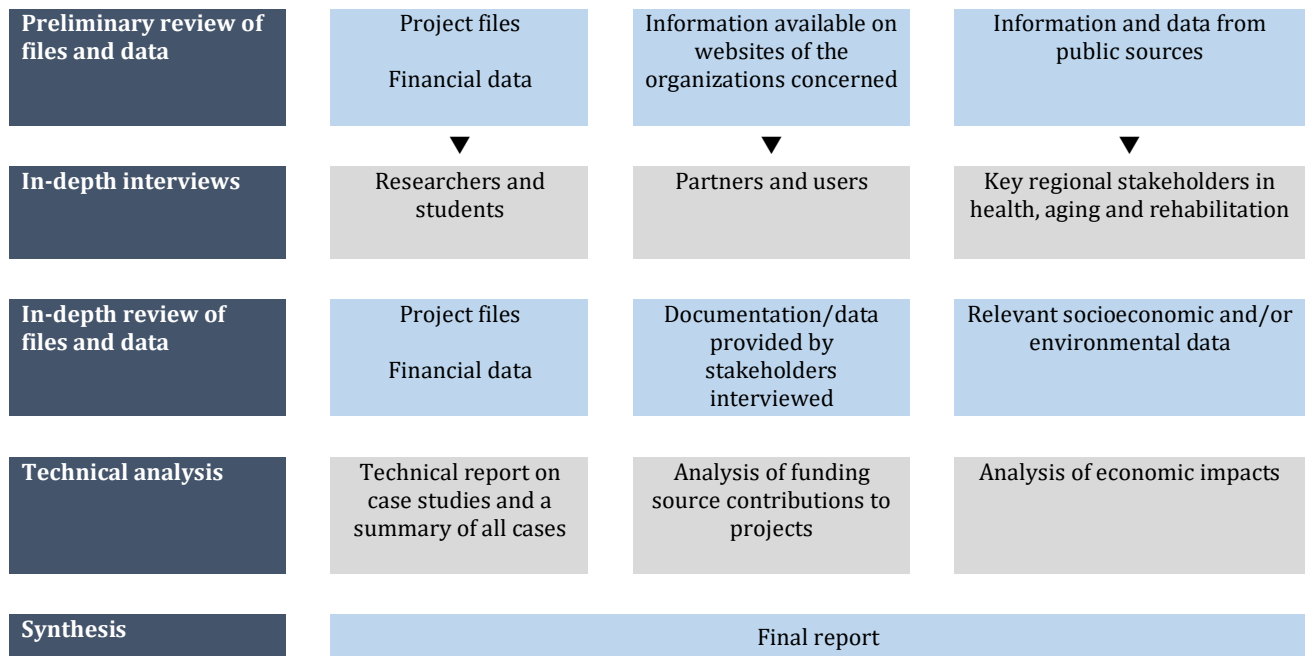
- **Document the nature and scope of regional socioeconomic impacts** (including the process that led to the various impacts) resulting from funding for post-secondary research on aging and rehabilitation in Estrie, primarily at Université de Sherbrooke and its affiliated hospitals
- **Demonstrate the complementary and synergistic nature** of different funding programs (e.g., material infrastructure, human infrastructure, research grants, fellowships)
- **Show decision makers, partners, governments and the public, the impacts** (economic, social, health, etc.) of research supported by the three partner organizations in multiple research sectors (natural sciences and engineering, health, social sciences and humanities, arts and letters).

Overall approach

Based on the number of projects with measurable results, the team opted for a case study strategy. The cases consist of research projects, the majority led by groups of researchers, on relatively specific themes. Data was collected through semi-directed interviews, documentation

review and a review of governmental data. At root, this approach collected descriptive (rather than comparative) information. The figure below summarizes our approach.

Figure 1: Summary of data collection and analysis methods



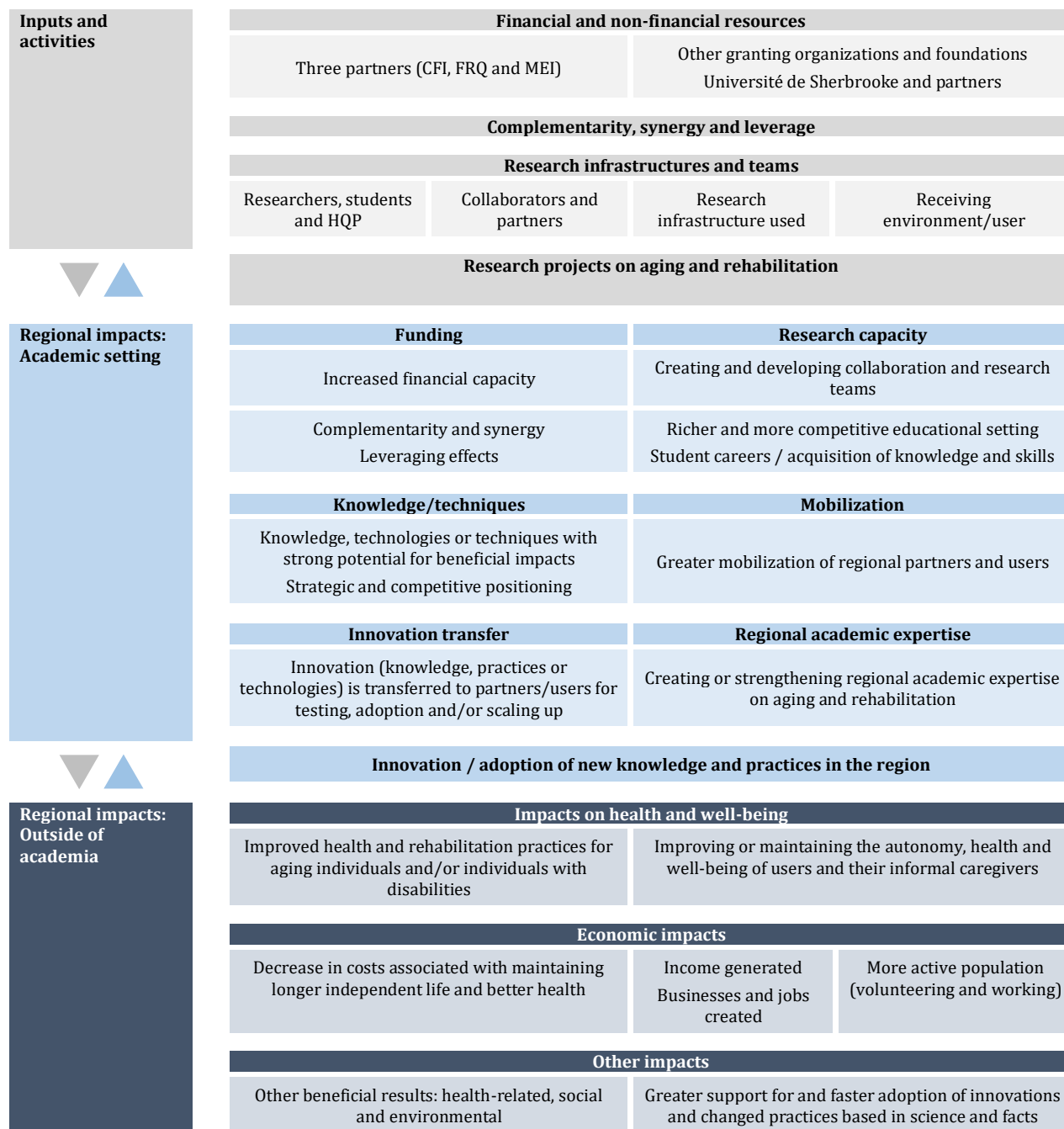
Case studies were preliminarily selected based on exploratory consultations with the primary stakeholders in aging and rehabilitation (CdRV and INTER/3IT). Nine cases were initially selected based on the maturity of their work. In other words, the cases were chosen based on the probability of measurable or observable impacts outside the academic setting. This number dropped to eight a short time after the fieldwork, as one of the cases proved to have progressed less than the rest. The cases selected are briefly described in the table below.

Table 1: Selected cases

	Case title	Objectives
1	Smart homes	Support the autonomy, safety and continued ability to live at home of individuals with cognitive impairment (schizophrenia, head trauma, intellectual impairment and dementia) and seniors who hope to remain at home, using smart homes (artificial intelligence technology and connected objects) capable of assisting occupants.
2	Telerehabilitation: TeraPlus telehealth platform project	Enable the remote delivery of rehabilitation care and services using a software platform to facilitate interactions, care (robotics) and transmission of the data needed to ensure service quality and accessibility and to preserve quality of life for patients and informal caregivers.
3	Actigraphy and kinematics of movement	Enable the remote delivery of care and services using a software platform to facilitate the collection of actigraphy data needed to help seniors and trauma victims with mobility.
4	Physical exercise during hemodialysis	Promote the benefits of healthy lifestyle habits and physical exercise during dialysis to improve the functional abilities of patients with diabetes, renal problems and other chronic illnesses experienced by seniors.
5	Neurostimulation therapy	Reduce the pain of seniors with chronic pain through neurostimulation with electrodes.
6	Non-pharmacological nutritional strategies for cognitive impairment	Prevent cognitive decline during aging (from mild cognitive impairment to Alzheimer’s disease) by developing a nutritional supplement (fatty acid and ketone).
7	Geriatric nutrition	Prevent malnutrition and nutritional deficiencies in hospitalized seniors and care home residents using dietary supplements to minimize weight loss, maximize lucidity and decrease medication use.
8	Living laboratory and mobility: The Mobilainés project	Co-create research projects, with and for seniors, on the reorganization of space, innovative communication and intersectoral partnership initiatives. These would be free from prejudice and take participants’ interests into account in order to make a real difference in the lives of seniors and create potential for sustainability.

A **logical framework** was developed to identify the main inputs, activities, outputs and impacts of funded research projects on aging and rehabilitation.

Figure 2: Logical framework



The team used this framework and a literature review to develop a list of indicators and interview guides (for project leads, for partners and for participants). A total of 44 interviews were conducted as part of the case studies. Four preliminary interviews were also conducted to identify and confirm the cases selected.

Fieldwork (interviews and document review) took place from December 2020 to March 2021. Due to the COVID-19 pandemic, interviews were virtual, taking place either by phone or by video conference.

The next two sections will present the study's results in terms of its primary objectives. Section 2.0 gives an overview of each case, and section 3.0 presents their impacts.

2.0 Overview of research projects

This section will present the research work associated with each case. Section 3.0 will offer a cross-sectional view of their impacts by type.

2.1 Smart homes

Approximately 75% of seniors in the Sherbrooke area live independently or semi-independently. Although independent living is both important to people and associated with numerous benefits, seniors living at home do face certain risks, including the risk of falls, poor diet, neglected health, accidents or fire. This is particularly true for those with cognitive impairment. The challenge is to help seniors remain at home while minimizing the risks associated with doing so.

Since 2002, the Laboratoire DOMUS of the Faculté des sciences at Université de Sherbrooke has been developing applications to help individuals with cognitive impairment maintain their autonomy. The laboratory includes three researchers: Sylvain Giroux (a member of the CdRV, INTER and 3IT), Hélène Pigot (a member of the CdRV, INTER and 3IT) and Charles Guoin-Vallerand (a member of INTER).

This project, like the others, received funding from multiple sources. In terms of infrastructure, initial contributions from the CFI and the MEI enabled the researchers to set up research spaces and acquire a variety of needed equipment such as computers, mobile devices and components. Computer infrastructure included servers, network access points and computers. Mobile infrastructure included an array of mobile electronic devices intended to cover a wide range of possibilities (various types of laptops, digital personal assistants, cellphones, etc.). Other infrastructure needs were fulfilled by setting up real environments supplied with furniture and household appliances, as well as a variety of sensors (presence, position, weight, warmth, ambient conditions). A second contribution enabled the researchers to purchase, assemble, install and program more sophisticated home automation devices (e.g., sensors, radio frequency routers, automatons) and computer equipment (e.g., servers and software).

Assisted by a number of students, the researchers developed three types of support systems: 1) cognitive assistance, including systems of reminders to take medication; 2) remote monitoring, involving a network of sensors and a video system to enable family caregivers and professionals to monitor users' behaviour; and 3) systems that notify the user if an appliance has been left on (the oven, for example) and/or can turn off an appliance that has been on for an extended period. They made use of technologies designed not only to protect users' physical safety, but also to indicate the extent to which users were taking their medications correctly, sleeping normally at night and eating at regular hours. Installing these systems entails a diagnosis and a needs assessment, the purchase and physical installation of devices, and training for users (and caregivers). These, then, are clinical, technological and organizational interventions. The success

of this project is due to a multidisciplinary team that brings together scientific researchers and professionals in the fields of occupational therapy, clinical implementation and computer science.

Systems have thus far been successfully installed in a three-dwelling residence in Estrie. The individuals currently living there can continue their lives independently and in full safety.

2.2 Telerehabilitation: TeraPlus telehealth platform project

Functional rehabilitation is an intervention aimed at helping an individual resume a normal life, such as after an accident or surgery. Unfortunately, the demand for rehabilitation services offered by outpatient clinics in hospital centres is generally greater than the available supply. This means significant delays in care, especially for patients with non-urgent conditions. Such delays can stretch to 18 months between assessment and the start of care. According to estimates based on 2017 data, approximately 20,000 people in Quebec were waiting for physical therapy services in hospital centres.⁵

Since 2011, Michel Tousignant, a member of INTER and the CdRV, has been working with other researchers of the Équipe Spécialisée en Téléréadaptation à Domicile (ESTRAD) [team specializing in telerehabilitation at home]. François Michaud, director of INTER and a member of 3IT, has also collaborated with Dr. Tousignant and other affiliated researchers (Hélène Corriveau and Patrick Boissy). These teams have helped to create and fully develop the telehealth platform TeraPlus, designed for telerehabilitation at home.

Infrastructure investments from the CFI and the MEI allowed the researchers to create a laboratory and bring on board Dr. Michaud's robotics expertise in 1998. The first contribution from the CFI and the MEI allowed researchers to purchase mobile robotics and systems intelligence equipment (e.g., mobile robots, sensors and actuators, an oscilloscope, computers, monitors, cameras and videos). A second contribution enabled the purchase of new video conferencing equipment for telerehabilitation (e.g., cameras) and computer systems for clinical and home stations (e.g., computers, flat screens, software). This equipment was used to develop prototypes for proof of concept, and, with around \$3 million in funding awarded by the Canadian Institutes of Health Research (CIHR) between 2008 and 2013, to carry out multiple large-scale clinical studies on rehabilitation.

The software was developed to be free and open source. From 2018 to 2020, the Fleurimont site of the CIUSSS de l'Estrie - CHUS participated in an implementation study that involved remote monitoring for 144 patients from its physical therapy outpatient clinic.⁶ This systematic remote monitoring was intended to provide patients with non-urgent conditions with an earlier start of care and, ultimately, to shorten the waiting list of the outpatient clinic. Although the results have not yet been made public, the preliminary results shared during interviews are encouraging. During the pilot project, wait times dropped from 18 months to 12 months. Since the start of the

⁵ Livre blanc sur l'accès aux services de physiothérapie au Québec [White paper on access to physical therapy services in Quebec]. Association québécoise de la physiothérapie. February 13, 2020.

⁶ https://www.medteq.ca/en/full_portfolio/implementation-of-telerehabilitation-as-an-innovative-modality-for-monitoring-patients-on-the-waiting-list-of-the-ciuss-estrie-chus-physiotherapy-outpatient-clinic-at-the-fleurimont-site/

pandemic, the ESTRAD team has collaborated with a number of private clinics and hospitals in Quebec and France to provide and implement the TeraPlus telerehabilitation platform.

Although the software is open source, the income from training in that software is a significant factor increasing the long-term viability of ESTRAD's work. ESTRAD currently supports at least five other institutions in France in implementing the TeraPlus platform, on the condition that they pay approximately \$5,000 for the TERA+ software, professional training and technical support.

2.3 Actigraphy and kinematics of movement

Advances in actigraphy (quantitative analysis of a person's activity) and kinematics of movement (measurements of movement quality) are known to have had significant effects on rehabilitation and on medical monitoring and follow-up with seniors. One day, these technologies should allow health care professionals to remotely monitor patients and thus to track health condition changes in seniors with decreasing autonomy (e.g., those with Parkinson's disease) living at home or in residential facilities. The technologies have additional applications in first aid (physical manipulation) for fragile seniors after serious falls, to avoid aggravating their conditions.

This case study primarily addresses two research advances based on actigraphy and kinematics of movement. These advances, made possible by the work of Karina Lebel (professor and researcher at Université de Sherbrooke and member of the CdRV), will improve outcomes for seniors with decreased autonomy. The first is in connection with Parkinson's disease; the second relates to a new tool, a smart dummy, which will improve care given to seniors after a serious fall. The Parkinson's disease research aims to provide tools to monitor Parkinson's patients' movements around their home, and thus to understand the effects of medication and make any necessary changes more quickly. It also aims to predict the illness's impacts on individuals' functional mobility, and the illness's progression independent of medication. The idea behind the smart dummy is to use inertial sensors (expertise developed by Dr. Lebel) to train first aid workers.

Following initial work on inertial measurement unit technology, the researchers found that a dummy fitted with instruments would be more useful than traditional methods for training first-aid workers in appropriate stabilization techniques. The first version of the dummy was tested in post-accident emergency simulations, and the tests were deemed conclusive. The recently developed second version of the dummy will be used to test manipulation techniques for rehabilitation of seniors after a serious fall.

The project had several sources of funding. In terms of infrastructure, the first contribution from the CFI and MEI allowed the team to purchase: a) a treadmill equipped with instruments to record data on a subject's strength, pressure and movement; b) an electronic walkway that measures temporal and spatial data on walking; and c) an electromyography (EMG) unit for assessing the electrical potential generated by cells. A second funding contribution enabled them to purchase a motion capture system (camera, emitters, and markers) to film a real person's movements and digitize them in order to convert them to a 3D animation.

Dr. Lebel's engineering expertise has led to significant advances in clinical knowledge, techniques and practices, for both Parkinson's disease and the smart dummy. For the Parkinson's project, the first clinical tests using inertial measurement units to assess mobility impairment have been

conducted with Parkinson's patients and deemed sufficiently conclusive to warrant a second, larger clinical study (currently in progress), funded by FRQS and conducted in collaboration with the Quebec Parkinson Network. In and of itself, this second study is a good indication of clinicians' level of receptiveness to this technology, and it brings the research team closer to their ultimate goal of reliable instruments that will enable neurologists to remotely assess the impact of Parkinson's disease and medication. For the smart dummy project, testing the second version of the prototype will help researchers to validate the importance of such a tool for training providers in various contexts to better help seniors who have fallen. If commercialization goes as hoped, the researchers expect the tool to get wide distribution and a great deal of visibility.

2.4 Physical exercise during hemodialysis

Chronic kidney disease (CKD) is characterized by a poorly functioning kidney that is incapable of doing its job of filtering and eliminating waste products from the blood. When treatment for CKD ceases to be effective, long-term hemodialysis (also called an artificial kidney) is one option available. CKD is associated with higher rates of mortality and a lower quality of life. Many sources show that physical exercise can slow the condition's progression and has positive effects on patients' sleep, mood, stress management and mobility, the last of which in particular helps them maintain their autonomy for longer.

Some years ago, the team of Mélanie Godin, a nephrologist and professor in the faculty of medicine and health sciences, approached Eléonor Riesco (principal investigator, professor and member of the CdRV and INTER) and Isabelle Dionne (scientific director of the CdRV and dean of the faculty of physical activity sciences) to set up a pilot project at the hemodialysis clinic of the Fleurimont site of the CIUSSS de l'Estrie - CHUS. This project was aimed at helping hemodialysis users, specifically seniors, to do physical exercise during their clinical treatment, which requires them to be in a stationary position for about 12 hour per week.

The FCI and MEI infrastructure funding was primarily used to purchase various devices for exercise and muscular training (e.g., treadmill, stationary bikes, free weights), as well as instruments for chemical analysis and electrocardiography, and a metabolic cart. Other funding sources helped to finance, among other things, the labour and materials to develop a prototype for a bicycle ergometer to support large-scale clinical research projects to build on the knowledge acquired from the pilot project.

The 2018 pilot project lasted six months and involved 17 participants who had three physical activity sessions per week, primarily using a bicycle ergometer prototype developed for the purpose. This was a pedal system fixed to a table, so that patients could pedal while staying in the position required for treatment. The success of the pilot project and the interest in this approach shown by several CIUSSSs led to a joint project with the CdRV to improve the bicycle ergometer, and another project to develop an implementation guide to help disseminate this approach (intradialytic exercise) in clinical settings. Two more projects are forthcoming: one to assess the clinical acceptability of a new bicycle ergometer prototype via testing in multiple CIUSSSs, and one to generate data from bicycle ergometers for large-scale analysis in order to validate the benefits of the approach for a large number of users.

The pilot project supported the hypothesis that intradialytic exercise is safe and feasible, and that senior hemodialysis patients appreciate it despite their diminished physical capacities and weakened state of health. Although the sample size was small, the project showed that supervised exercise by senior patients is an effective strategy for maintaining their functional capacity and quality of life and increasing the effectiveness of dialysis, due to this population's low level of physical activity and high risk of loss of functional autonomy. The project's achievements also included research support for improving the bicycle ergometer and developing it into a tool that could be widely deployed in clinical settings at an affordable cost (potential commercialization). Future studies will help to validate the benefits of intradialytic exercise in a greater number of patients. In the longer term, the researchers hope to expand intradialytic exercise to include chronic kidney disease patients who receive hemodialysis treatment at home.

2.5 Neurostimulation therapy

Approximately one in three Canadians aged 65 and up lives with chronic pain.⁷ The consequences of pain on individuals and their families are increasingly well understood, and include a decrease in mental and emotional health, cognitive function issues, fatigue and issues with sleeping, a decrease in activities of daily life, and so on. Chronic pain often has greater impacts on seniors, since they are more likely to have medication intolerances and medication side effects are often more intense. In addition to the physiological, mental and social consequences of chronic pain, there are also steep economic costs. In Canada, the total combined direct and indirect costs of chronic pain are approximately \$56 billion to \$60 billion every year.⁸

Guillaume Léonard, a member of the CdRV, has been working with a team of Université de Sherbrooke researchers since 2012 on the efficacy of neurostimulation in reducing or eliminating patients' chronic pain. In particular, Dr. Léonard's team is studying a non-invasive method involving electrodes applied to patient's heads. This treatment involves a neurological stimulation (not neurological reduction). The team is specifically interested in using the treatment for seniors.

The research team has been awarded several grants since 2014. In particular, grants from the CFI / government of Quebec and the Natural Sciences and Engineering Research Council of Canada (NSERC) have played a major role in helping the team and its work get started. The contribution from the CFI and the MEI was primarily used to purchase transcranial magnetic stimulation platforms (a non-invasive neurophysiological method for inducing electrical currents in the brain) and a neuronavigational device for precise positioning of electrodes.

The team has done a great deal of research work to shed light on the relationship between pain and the nociceptive⁹ and motor systems in seniors and young adults. Léonard has also worked steadfastly to get this therapeutic approach approved, including securing Health Canada approval for the devices and approval of the treatment techniques from Quebec's professional association of physical therapists. The team has treated a number of patients in the university's laboratories and successfully integrated the therapy into a clinic in Sherbrooke and another in Rouyn-Noranda. Patients have typically seen pain levels decrease from intense to light/moderate after the teams'

⁷ Ibidem

⁸ Ibidem

⁹ Nociceptors are pain receptors located throughout the body. When they detect harmful stimuli, they raise the alarm by signalling pain. (Source: Institut National du Cancer, France)

work. In some cases, pain has completely disappeared. In addition to reducing pain itself, direct impacts on patients' quality of life have been observed, including a decrease in medication use and a corresponding decrease in medication side effects; better sleep and a feeling of well-being; resumption of physical and social activities; and, in some cases, the ability to keep a job or return to work.

2.6 Non-pharmacological nutritional strategies for cognitive impairment

Aging is the primary risk factor for the majority of neurodegenerative diseases, including dementia. Evidence shows that the neural degeneration and cognitive decline that characterize dementia (including Alzheimer's disease [AD]) have wide-ranging effects on not only the affected individual, but also their loved ones and caregivers and society as a whole. Although there is currently no cure, some pharmacological treatments can ameliorate some dementia symptoms and/or slow its progression for some people. Some researchers believe that the efficacy of such treatments would be optimized if begun at an early or prodromal stage of the disease.

A connection between reduced glucose metabolism in the brain and the development of AD had already been established, so Stephen Cunnane and his CdRV team began research on assessing non-pharmacological nutritional strategies to compensate for cerebral energy deficits using an alternative fuel source, ketones.

The infrastructure needed for the project was acquired using 2004 grant funding from the CFI and the government of Quebec, along with a Canada Research Chair on brain metabolism and aging. Two contributions from the CFI and the MEI enabled the researchers to acquire specialized instrumentation such as an atomic absorption spectrophotometer, a Carbon-11 radiosynthesis module and an ultra-high-performance liquid chromatography tandem mass spectrometer (UHPLC-MS). This instrumentation supported the development of new imaging approaches, enabling the team to identify early markers of the AD degenerative process, and was used to compare brain metabolism of glucose and ketones.

Developing 11C-acetoacetate ([11-C]ACAC) as a ketone tracer for positron emission tomography (PET) allowed Dr. Cunnane and his team to compare the same individual's brain metabolism of glucose and ketones. They then developed a new imaging analysis technique for following the [11C] ACAC tracer in the relevant region of the brain. Using this, they found that certain regions of the brain have an energy deficiency¹⁰ in AD patients. They developed a dietary supplement (a drink containing medium-chain triglycerides [kMCTs]) to increase the brain's ability to capture ketones, and observed an improvement in the net energetic state of the brain for patients with mild cognitive impairment (MCI).

Dr. Cunnane and his team found the regional deficiencies in brain glucose absorption associated with MCI to be approximately 10%, compared to over 20%–25% in AD patients. They then assessed cognitive changes in MCI patients through a randomized controlled trial called BENEFIC. The first phase was funded by the Alzheimer's Association USA and the second by Nestlé Health

¹⁰ Insufficient brain glucose and inadequate ketone response create mild but chronic energy deficiencies in regions of the brain that consume large amounts of energy.

Science. The BENEfIC study found that a kMCT drink improved MCI cognitive outcomes for episodic memory, executive function and language. The study's data showed that a significant increase in ketones provided an alternative fuel to an aging brain that is "low on energy," and thus helped to slow the progression toward AD. Based on Dr. Cunnane's research findings, Nestlé Health Science has created a formula with the same active ingredients to commercialize the kMCT drink. It was brought to market as BrainXpert Energy Complex in October 2020.

2.7 Geriatric nutrition

A reported 60% of residents of hospital long-term care centres (CHSLDs) in Quebec are at risk of malnutrition. Malnutrition and weight loss have serious consequences for residents of long-term care homes (LTCHs), including higher risks of mortality and of morbidity such as pressure sores, infections, delirium and falls.

Since 2017, Nancy Presse and her CdRV team have been developing and testing the Nutrition as Medication (NAM) intervention, inspired by the "Med Pass" approach that originated in the United States in the 1990s. This intervention suggests prescribing small doses of an oral nutritional supplement to be administered like a medication, one to four times daily. The NAM program developed by Dr. Presse and her team is a strategy for improving compliance with prescriptions for oral nutritional supplements (ONSs) by providing 30 ml or 60 ml doses of ONSs during medication administration rounds, up to four times per day, rather than offering a full portion of an ONS (around 240 ml) as a snack or with meals. Dr. Presse and her colleagues had previously done an exploratory literature review to clarify key concepts for ONS administration during medication rounds, to find existing evidence for their strategy and to identify gaps in the knowledge base. They then conducted a six-month controlled pilot trial in two long-term care units at a Sherbrooke hospital, followed by a randomized controlled trial in a larger Montréal hospital with nine long-term care services. The next phase of the study will be to guide and assess the implementation of NAM in two LTCHs in Montréal.

Data from the controlled pilot trial in Sherbrooke found that patients who received ONSs under the NAM program had a higher rate of compliance with ONS prescriptions and a significantly higher body mass index (BMI) compared to patients in the control group. The data from the randomized controlled trial in a Montréal hospital are still being analyzed. Nonetheless, it is worth noting that the LTCH chose to deploy NAM in all nine of its units at the end of the study, based on the positive experience reported by nursing staff. Preliminary results on the efficacy of the NAM program with residents of the Montréal LTCH show a high rate of ONS prescription administration and compliance, a significant improvement in nutritional status and a decrease in pressure sores. NAM appears to be a promising practice that could limit or prevent nutritional deterioration in LTCH residents.

2.8 Living laboratory and mobility: The Mobilaînés project

Seniors' social participation is intimately linked to their access to transportation. Such access, however, varies depending on their resources and, of course, their level of autonomy. Transportation costs are a limiting factor that can represent a major burden for aging seniors.

For over 30 years, the CdRV's interests have included the connections between transportation and seniors' quality of life. In 2017–2018, an internal grant allowed researchers to create the CdRV's first living laboratory, the Laboratoire d'innovations par et pour les aînés (LIPPA) [Laboratory of innovations by and for seniors]. Among other projects, LIPPA supported the Mobilaînés project, for a one-stop portal for mobility, co-created by and for seniors to increase their autonomy.

Mobilaînés was launched in November 2019 using FRQ funding for a program aiming to address major societal issues. Its objective is to develop and test a central portal to help seniors travel “wherever, whenever and however they want.” The project is jointly led by Véronique Provencher (professor in the school of rehabilitation in the faculty of medicine and health sciences, and member of the CdRV) and Dany Baillargeon (professor in the communications department of the faculty of letters and the humanities). It aims to unite under one “roof” all existing transportation options that are solidly established in the community, to help enable seniors to use them and make informed decisions. Mobilaînés includes more than nine public and community organizations in Estrie, including the Centre des activités de Sercovie (Carrefour des aînés) [Sercovie activity centre (hub for seniors)], the CIUSSS de l'Estrie - CHUS, the city of Sherbrooke and the Société de transport de Sherbrooke [Sherbrooke transportation authority].

Thus far, the intersectoral research team has identified needs, obstacles and issues related to the mobility of seniors by soliciting them through local community organizations and partners. Seniors' accounts of their experiences have helped the team to create various mobility profiles in as many contexts as possible. The research team has done a census of pre-existing travel planning assistance systems and tools. They have created a directory of 45 tools, with an analysis of the 11 tools that have common features and were identified as the most inspiring and innovative: making filters and/or route choices available, providing information in real time on the status of the transportation system and showing routes on an interactive map. The researchers then consulted with a steering committee on the criteria to prioritize for an ideal tool for the Mobilaînés portal. The steering committee is a multidisciplinary, multisectoral committee made up of researchers, professionals in the field and partners. Many members of LIPPA's seniors committee and representatives from the project's partner organizations are members of the steering committee. LIPPA's seniors committee will use a codevelopment workshop to validate the criteria selected.

The last steps of Phase 1 will be to propose avenues for potential solutions to the needs and issues identified, as well as to confirm key partners for the next phases of creating and implementing the portal. It is still too early to measure the project's concrete impacts for Sherbrooke seniors.

3.0 Project outcomes

The outcomes of these projects vary depending on how far the work has progressed, and include both academic outcomes and broader socioeconomic impacts. This section presents these end results, beginning with the academic outcomes.

3.1 Outcomes in academic settings

Synergy of funding sources

The projects were supported by many funding sources, including government and their research funding agencies, foundations and private companies. Details of all funding sources are presented in Appendix A. Table 2 summarizes the amount of funding per project.

Table 2: Funding per project

Project	Funding
Smart homes (2003–2020)	\$3,229,678
Telerehabilitation: TeraPlus telehealth platform project (1998–2020)	\$5,038,186
Actigraphy and kinematics of movement (2014–2020)	\$4,059,205
Physical exercise during hemodialysis (2007–2020)	\$730,398
Neurostimulation therapy (2014–2020)	\$2,100,201
Non-pharmacological nutritional strategies for cognitive impairment (2015–2020)	\$3,703,168
Geriatric nutrition (2016–2020)	\$442,230
Living laboratory and mobility: The Mobilainés project (2017–2020)	\$2,182,768

Note: Some minor funding sources have been omitted.

The details of the direct funding received per year (see appendix) indicate that the funding sources generally follow an order: in four cases, the first grant came from the CFI / Quebec government. These four cases included the projects on **telerehabilitation**, on **smart homes** and on **non-pharmacological nutritional strategies for cognitive impairment**:

The project on **telerehabilitation** received a number of grants over the years. It was the infrastructure investments from the CFI and the MEI, however, that enabled Dr. Michaud to establish his laboratory and expertise in robotics starting in 1998, and enabled Dr. Tousignant to purchase telehealth equipment in 2003. This equipment has been used to conduct numerous large-scale clinical studies on the efficacy of telerehabilitation.

The project on **smart homes**, like the others, benefited from various sources of funding. Investments from the CFI and the Quebec government laid the foundations in terms of infrastructure, making it possible to develop research spaces and establish a laboratory on

campus. Later funding (for example, from NSERC and CIHR) was used to develop a research program within the INTER strategic cluster financed by the FRQNT, and to recruit student researchers and research professionals to develop applications that promote autonomy and help seniors stay in their homes longer.

In 2004, grants obtained from the CFI and the Quebec government allowed Dr. Cunnane to start the project on **non-pharmacological nutritional strategies for cognitive impairment**. These grants enabled his team to acquire infrastructure, including new imaging analysis software. After the imaging infrastructure was in place, Dr. Cunnane received funding from NSERC and CIHR to continue his research on aging. More specifically, this funding allowed him to carry out imaging studies to observe the brains of individuals with MCI and develop a kMCT drink aimed at increasing the brain's net energy levels in such individuals.

In other cases, it was initial support from the FRQ that allowed inception of research projects (such as for the CdRV or INTER's research programs). Researchers explained that by allowing them to purchase equipment and other essential starting infrastructure, to acquire deeper knowledge (literature reviews, etc.) and to attract collaborators, this funding helped them build their research team and launch their research projects. For example:

For the project on **physical exercise during hemodialysis**, FRQS funding in 2007 enabled Dr. Dionne to get a release for knowledge enrichment and research. The release not only enabled her to acquire the initial knowledge on which she based the project on physical exercise during hemodialysis, but also gave her the opportunity to support Dr. Riesco when she joined the team and to position her within this research area.

Other funding sources followed, in many cases due to the leveraging effect of that initial support. These second and third sources or contributions were often used to obtain the services of research professionals, replace obsolete equipment and attract and retain graduate students. These contributions made it possible for researchers to continue and accelerate their work, as well as to broaden its scope.

Subsequent grants often allowed the research to move to a preclinical or trial phase. For example, in the study on **geriatric nutrition**, after the promising preliminary results of the pilot study and randomized controlled trial, Dr. Presse received a grant from CIHR in 2020 to test a NAM implementation kit in two Montréal LTCHs. Likewise, the project on **non-pharmacological nutritional strategies for cognitive impairment** received funding (one from the Alzheimer's Association, two from Nestlé Health Science) for applying the BENEFIC trial's knowledge, practices and techniques to new research themes, including a pilot project to measure the heart's ketone usage and a clinical trial to measure the effects of ketone salts on brain function in individuals with MCI.

Research group creation and development

As mentioned above, the immediate result of funding is often the creation of a local research group that includes faculty researchers, research professionals and students at various levels. The research group ensures that there is a critical mass, continuity of research work and most often a multidisciplinary vision due to the fact that members often come from a range of disciplines. This

combination of varied expertise is frequently essential to the success of research work ultimately aimed at actions with a direct impact on users.

In the project on **physical exercise during hemodialysis**, for example, the intervention was made possible by collaboration between professionals in the medical sciences and physical activity sciences. These specialists also worked with an engineer to create a bicycle ergometer tailored to their patient population. In other cases, the funding of a research chair enabled researchers to set up a structure for starting and/or ensuring the continuity of research projects. This was the case for the institutional research chair in **telerehabilitation** (Vitae Foundation / Fondation de l'Université de Sherbrooke) and for the research on **non-pharmacological nutritional strategies for cognitive impairment** (Université de Sherbrooke research chair on brain metabolism and cognition during aging).

Interdisciplinary knowledge

Behind multidisciplinary work is the development of know-how, the abstract nature of which is often underestimated. Sustained funding of a research group, or at least of researchers working in collaboration, not only supports teamwork, but also the development of essential know-how for interventions that are multidimensional, including ones that incorporate interactions between mechanical instruments, medications/supplements and human beings. This know-how is built through multiple years of work on specific applications, in collaboration with specialists in complementary disciplines.

For instance, the **smart homes** project actually includes a number of smaller projects aimed at adapting home appliances. Installing sensors and timers, for example, required contributions from several specialists in areas including computer science and engineering. Some components of the project fall more on the “human” side of this work, and were made possible by contributions from specialists in occupational therapy and nutrition. Over time, as they’ve participated in these projects, the specialists have developed invaluable expertise in interdisciplinary work. While the team dedicated a great deal of efforts to adapting their first home appliances, as they have developed specialized components, they have acquired more skill at maximizing their use of commercial products and thus minimizing the amount of redesigning and transformation they need to do themselves. These skills are rooted in a better understanding of both the workings of appliances and the needs of their users.

To take another example, interdisciplinarity is at the heart of the **Mobilaînés** project. The principal investigators come from the school of rehabilitation in the faculty of medicine and health sciences and from the communications department in the faculty of letters and the humanities. The team also includes researchers specializing in the development of health technology (Bessam Absulrazak and Patrick Boissy). The project is led by a multidisciplinary and multisectoral steering committee made up of researchers, community stakeholders and other partners. The results of implementing the Mobilaînés project’s approach “by and for” seniors in an academic setting have been significant thus far, both for training students and for interdisciplinary networking. At the social level, the case study highlights how the Mobilaînés project’s co-creation process has increased partners’ and students’ sensitivity to the experiences of aging seniors.

Students' learning and career development

Our case studies demonstrate that research projects are of great benefit to students. All the projects included the participation of students, as research assistants and/or as student researchers whose master's or doctoral work was connected to the work of the research teams. At least 69 students and fellows from Canada and abroad participated in research work (see Table 3), including both undergraduate and graduate students, post-doctoral researchers. These students benefited from the research infrastructure to carry out their work and the learning associated with participating in research groups.

For example, Karina Lebel (**Actigraphy and kinematics of movement**) is currently supervising two master's students (motion signatures and the smart dummy), one undergraduate student (Parkinson's and smart dummy), one doctoral student (small facial movements) and two research assistants (data analysis and Parkinson's), and will soon supervise a post-doctoral fellow (Parkinson's). In the past, a doctoral student (Parkinson's), two undergraduate students (kinematics) and one research assistant (smart dummy) have also been able to take part in Dr. Lebel's research. Funding for the smart dummy has also helped to train students in physical therapy. It is worth noting that Dr. Lebel herself was also awarded an FRQ excellence scholarship during her doctoral studies, which helped her begin her research work in this area.

As part of the **Mobilaînés** project, students have used the "living laboratory" and co-creation approaches with seniors as part of their master's and doctoral theses. This approach requires students to become familiar with new methods of consultation and knowledge transfer with seniors, partners and students in other fields and to acquire a new understanding of seniors' experiences. Many students have led workshops with the steering committee and have helped to create logbooks for the Mobilaînés project. These logbooks formalize the co-creation process, while making the information contained in them as accessible as possible to a wide audience, and thus as relevant and interesting as possible for seniors and project stakeholders.

Thesis work typically helped students delve into promising research areas and actively contribute to knowledge development within their research team. For example:

One person completed their Ph.D. in pulmonary **telerehabilitation** in 2014, under the supervision of Dr. Tousignant. Their work comparing traditional pulmonary rehabilitation with pulmonary rehabilitation via telerehabilitation showed that the study population of patients with chronic obstructive pulmonary diseases (COPDs) were highly sensitive to temperature changes, meaning that it was extremely beneficial for them to receive their rehabilitation treatments without leaving their homes. Their work was used in developing

Table 3: Participation of students, fellows and research professionals

29	Master's students who participated in research work
20	Doctoral students who participated in research work and/or did thesis work on related subjects
11	Post-doctoral researchers who participated in research teams
9	Undergraduate interns who participated in research work
11	Research professionals who participated in research work

guidelines and educational videos to help health care professionals (Living Well with COPD).

Participating in projects helped students to get funding for their studies and/or acquire knowledge in a specific field of specialization. Many later took positions in the health care field or in academia. Dr. Cunnane (**non-pharmacological nutritional strategies for cognitive impairment**) reported that eight of his former student researchers have since held positions as university professors in Canada, the United States, Europe and Hong Kong. Below are examples from other cases:

One individual completed their post-doctoral fellowship with Michel Tousignant in 2013 on satisfaction levels (barriers and facilitators) with the implementation of telerehabilitation after total knee prosthesis. This individual is now an associate professor at the Université de Montréal school of rehabilitation.

Another individual supported as a part-time research assistant and later as a project coordinator the projects of Dr. Tousignant and Dr. Corriveau. This individual was later hired as a telehealth advisor at the Centre de coordination de la télésanté (CTT) [telehealth coordination centre] of the CIUSSS de l'Estrie - CHUS. They feel that working for the Université de Sherbrooke research chair in telerehabilitation as part of ESTRAD is what enabled them to gain technical and cross-sectoral research skills for the technological and clinical environments required in telehealth work.

3.2 Socioeconomic impacts

This section will present the socioeconomic impacts of the research projects. These include direct impacts on seniors and other patient populations, as well as on organizations and institutions both directly and less directly involved.

3.2.1 Impacts on seniors' health and well-being

The ultimate objective of all the research projects was to improve seniors' health and well-being. In pursuit of this, research work went through various stages, including research, clinical trials, prototype testing, pilot projects and, in some cases, small-scale implementation involving the participation of workers, service providers and a target patient population. Although the work often remains on a limited scale, some have already demonstrated impacts for the target population, or at least showed very promising results in advance of further trials. These results show impacts through improvements in diet, medication use, care, access to care and autonomy, depending on the project.

Improved diet and medication use

Some cases saw success with diet and medication use. Good nutrition, in particular, is an issue challenging thousands of seniors on a daily basis. Over 60% of CHSLD residents in Quebec are reported to be at risk for malnutrition.¹¹ One of the cases (**geriatric nutrition**) focused on this

¹¹ Roy, S. (2013). Le plaisir de manger: guide de meilleures pratiques en matière d'alimentation dans les CHSLD, Longueuil : Agence de la santé et des services sociaux de la Montérégie.

issue by adapting the NAM program for seniors. Nancy Presse tested this intervention, which uses small doses of an oral nutritional supplement administered multiple times per day. Currently, the team has conducted a pilot trial with a comparison group with approximately 30 users in a Sherbrooke hospital. The trial has had positive results both in knowledge gained and for the participating users. These include:

- Better compliance with nutritional prescriptions
- Reduction in pressure sores for participants
- Significantly higher body mass index (BMI) for participants (compared to those receiving a supplement under the standard regimen)

At the time of writing, a second and larger scale pilot project in Montréal is nearly complete. Other projects have shown similar results. The **smart homes** project includes training and adapted devices that help participants become more dietarily independent (by safely cooking their own healthy meals). Home automation and remote monitoring technologies allow users to be more effectively monitored to ensure that they are taking their medications correctly, sleeping normally at night and eating at regular times.

Improved care

Several projects contribute directly to better care for seniors in Estrie. The **neurostimulation therapy** project has a direct positive effect on seniors' health and quality of life. This project, which began in laboratories at University de Sherbrooke, later received the necessary approvals for implementing neurostimulation beyond the university in multiple clinics around Quebec. The results show that this new therapy is effective at reducing certain types of chronic pain. The majority of patients found that their chronic pain had dropped from an intense level to a light/moderate level. In addition to reducing pain, the therapy was observed to have direct impacts on other aspects of patients' lives, including:

- Reduced medication use, and a consequent reduction in associated medication side effects
- Better sleep and feelings of well-being
- Resumption of physical activity
- Resumption of social activities, such as caring for grandchildren

At this stage, approximately 60 patients have benefited from this therapy (in Estrie), and an additional 30 or more will do so in the coming years.

The **physical exercise during hemodialysis** project has also had positive effects on the health of participants in Estrie. Treatment using a bicycle ergometer to provide intradialytic exercise has shown that supervised exercise for senior patients can be an effective strategy for improving their functional capacity and quality of life as well as dialysis efficacy. The results show that patients have significant improvement to the muscular capacity (strength and stamina) of the lower limbs, improved quality of sleep and fewer depressive symptoms and, for 25% of patients, improved dialysis treatment. An upcoming study with a larger number of participants (in Estrie and

elsewhere in Quebec) and an improved bicycle ergometer should confirm the benefits of physical exercise for seniors who receive hemodialysis.

Improved access to care and treatment

Seniors make up a significant proportion of rehabilitation services recipients. As mentioned in the introduction, the goal of rehabilitation is to enable an individual to readapt to normal life, such as after an accident or surgery. Unfortunately, the demand for rehabilitation services offered by outpatient clinics in hospital centres is generally far greater than the available supply, leading to considerable wait times. Non-urgent patients are typically assessed and placed on a wait list for possible face-to-face care 18 months later. Such delays often lead to the development of more chronic conditions.

In this context, the **telerehabilitation** project is a very promising mechanism to increase prompt access to care. Between 2018 and 2020, the Fleurimont site of the CIUSSS de l'Estrie - CHUS participated in a remote monitoring program with 144 patients from its physical therapy outpatient clinic. The aim of these remote sessions was to decrease the delay before patients received care for non-urgent conditions, and ultimately to shorten the outpatient clinic's wait list. Over the course of the pilot project, wait times dropped from 18 months to under 12 months. Telerehabilitation also reduced the absentee rate and increased access to services for more vulnerable or more disadvantaged patients. Monthly telerehabilitation sessions, therefore, increased the quality of follow-up for these patients and helped relieve waiting lists via a better case closure rate.

Although the **Mobilaînés** project is still in development, it has already helped increase seniors' mobility and access to multiple services, including health services. The objective of Mobilaînés is to provide a single portal to help seniors travel "whenever, wherever and however they want," using an online application or a phone system. The service shows the user the best transportation methods for reaching their destination, depending on their request parameters and available transportation sources. At this stage, the project has helped to bring together pre-existing initiatives like Embarque Estrie (an online platform to make it easier to search for public transit and active transportation options available in Estrie) and the work of the steering committee of the Centre de mobilité durable de Sherbrooke [Sherbrooke sustainable mobility centre]. This committee was already carrying out initiatives similar to Mobilaînés, but for all public transit in Sherbrooke. When complete, the project will help to make transportation easier for seniors and service providers, including Carrefour des aînés [hub for seniors], which offers a range of care and food services for seniors. A single portal like Mobilaînés will be extremely useful in streamlining travel for seniors and volunteers travelling to and from the Centre de services.

Remaining at home

In general, the projects detailed above contribute to better care and better access to care, and thus help seniors to have better overall quality of life and, in many cases, to continue living at home. The primary objectives of some projects, however, are focused on helping seniors who are losing their autonomy to have a longer independent life, whether by helping them to take care of themselves in their own home or by helping them to access the services they need.

The main objective of the **Mobilâînés** project, for example, is to assist seniors who cannot independently travel (i.e., by car). Travel assistance allows them to access services, which helps them live independently. The **physical exercise during hemodialysis** project, as well, helps to maintain body mobility and independence for seniors with kidney disease by maintaining and strengthening their muscular capacity using a bicycle ergometer. Neurostimulation may also have a similar effect, since some **neurostimulation therapy** patients were able to resume normal physical activities.

Furthermore, although Dr. Cunnane’s research work (the **non-pharmacological nutritional strategies for cognitive impairment project**) is still in development, preliminary results suggest that the kMCT drinks help to improve cognitive abilities in the domains of episodic memory, executive function and language. If current research confirms these results, the kMCT drinks will delay cognitive decline in some patients and help them to maintain an independent life, including by assisting their family caregivers.

More directly, the **smart homes** project showed how a holistic approach that relies on home automation and an integrated support and remote monitoring approach can help seniors maintain their quality of life at home. “Smart” devices and remote monitoring methods can reduce seniors’ risks of accidents or neglecting self-care, so that they can continue to live independently. Self-neglect includes a range of multi-faceted behaviours involving the refusal or inability to adequately care for one’s own basic needs (health, hygiene, nutrition, social needs, etc.). The project results showed that its integrated approach, which included technology, training and remote monitoring, helps to maintain seniors’ quality of life and enable them to spend longer living at home before needing to move to an intermediate resource or CHSLD.

Lastly, and particularly worthy of note, is Dr. Lebel’s work on **actigraphy and kinematics of movement** to improve outcomes for seniors with Parkinson’s disease. A currently ongoing study is expected to validate the benefit of tools to help neurologists to better monitor these patients remotely, and thus to improve their quality of life at home.

3.2.2 Impacts on the health and well-being of other populations

Beyond seniors

By their nature, some projects have also benefited younger populations facing issues similar to those of seniors. There are younger populations that receive rehabilitation or deal with chronic pain who could also benefit from the approaches explored in projects such as those on **telerehabilitation** and **neurostimulation therapy**. Some younger populations must also rely on dialysis, even if less commonly than seniors, and could also benefit from the bicycle ergometer. In some cases, as well, the new methods of care have proved effective for other health problems. For example, continuing research on neurostimulation has shown that it can be effective for patients with paralysis after a cardiac event.

Many younger people may also have conditions that affect their cognitive abilities. In fact, younger populations that face risks similar to those of seniors losing their independence have already benefited from components of the **smart homes** project. Similarly, other populations could benefit from the results of the **geriatric nutrition** project and the kMCT drink for patients with

cognitive impairment. Lastly, in the case of the **actigraphy and kinematics of movement** project, the resulting smart dummy will be useful not only for improving the handling of seniors after serious falls, but also any other population after serious accidents (automobile, ski, etc.).

People in other regions of Quebec and internationally

Estrie users have reaped the lion's share of the benefits of the health and well-being impacts described above. However, applications were implemented in other regions as well in the cases of the projects on **neurostimulation therapy, physical exercise during hemodialysis, smart homes** and **geriatric nutrition**. For example, a clinic in Abitibi is using neurostimulation on a regular, non-experimental basis. As for the **telerehabilitation** project, ESTRAD has developed collaborations with Parisian teams and installed their telerehabilitation platform software at two clinical sites (Centre Paris-Est, and Sainte-Marie); nearly 800 telerehabilitation sessions were carried out there in 2020.

3.2.3 Impacts on local organizations

Within the Estrie region, some local institutions and organizations involved in the projects also saw an impact. This is especially true for the organizations currently involved in the **Mobilainés** project, including

- Lennoxville and District Community Aid
- Centre des activités de Sercovie (Carrefour des aînés)
- CIUSSS de l'Estrie - CHUS
- Corporation de développement communautaire de Sherbrooke
- Société de transport de Sherbrooke (STS)
- Table de concertation des aînés-es de l'Estrie (TRCAE)
- Ville de Sherbrooke

Since the project is still in its early stages, any results for these stakeholders are currently preliminary. These include increasing various partner organizations' awareness of certain issues that seniors face and the organizations' familiarity with local agents of change, and connecting partner organizations who had no relationship prior to the project.

For organizations that provide services to seniors, new tools that allow them to better serve their clientele have a major impact. For example, **neurostimulation therapy** is now an additional care method available for a Sherbrooke clinic. **Telerehabilitation** enables service providers to expand the scope of their services to more people. For its part, the **smart homes** project has not only had a positive impact on seniors, but also on landlord organizations by reducing the risk of accidents and fires. This secures the occupants and the owners of the premises.

Finally, some projects have given rise to the creation of new organizations. In the case of the smart homes project, a cooperative is currently being developed to facilitate the installation of a greater number of intelligent dwellings.

3.2.4 Economic impacts

Although the projects did not aim to produce so-called economic impacts, it is possible to identify several impacts that can be quantified monetarily. In most cases, this is due to innovations that enabled costs to be avoided, but some also led to revenue. The economic impacts can be categorized as follows:

BETTER USE OF PROFESSIONAL TIME. The **telerehabilitation** project’s technology allowed for remote services with a higher rate of efficiency, because a greater number of patients could be seen per professional work hour. The system’s savings for a team of five physical therapists are estimated at approximately \$250,000 annually (for a 25% increase in efficiency). Note that this calculation does not take into account any benefits and cost savings attributable to a) reduced user travel, b) faster care therefore, enhanced recovery of users, and c) better quality of life and greater autonomy for users.

Table 4: Potential savings for a practice with a team of five physical therapists, from increased efficiency due to telerehabilitation integration

	Five (5) physical therapists
Daily wages (\$55/hour x 7.5 hours)	\$2,438
Number of physical therapists per day	5
Number of patients per day	30
25% increase scenario	45
Cost per patient per day	\$69
25% increase scenario	\$46
Savings per patient per day	
25% increase scenario	\$23
Savings per day	
25% increase scenario	\$1,031
Savings per year (48 weeks of work @ 37.5 hours/week)	
25% increase scenario	\$247,500

Note: Median hourly pay rate of physical therapists Quebec-wide, 2018–2020: \$38.46 + 35% benefits = approximately \$55. ([Emploi-Québec](#))

MAINTAINING AUTONOMY. In many cases, innovations helped seniors prolong their independence. This is economically important because people housed in intermediate resources (IRs) and CHSLDs cost the government a significant amount of money; an IR resident, for example, costs the government of Quebec approximately \$120 per day. Seniors who live at home, therefore, can represent significant savings for the state. The **smart homes** project is already helping some individuals remain independent, and the **Mobilâinés** project may do likewise in the future.

PREVENTING THE NEED FOR MEDICATION OR CARE. Some cases have also resulted in less need for medication. This includes the **neurostimulation therapy** project, whose positive impact on chronic pain could decrease the use of pain medications (approximately \$1,200 per patient per

year). Table 5, below, illustrates the estimated costs avoided by patients who have received neurostimulation treatment over the last two years. We can extrapolate these calculations to estimate that 1,000 seniors benefiting from the treatment would lead to savings of approximately \$1.2 million per year in medication alone.

Table 5: Costs avoided to date by reduced medication use

Type of impact	Estrie	Abitibi	Total
Decreased medication use (costs avoided)	60 patients x \$1,200 x 2 years = \$144,000	43 patients x \$1,200 x 2 years = \$103,200	\$247,200

IMPACT ON INCOME. In some cases, better care allows patients in younger populations to continue to hold a job or to return to the labour market. This was true for some patients receiving **neurostimulation therapy**.

OTHER SAVINGS AND INCOME. Although secondary at this point, there are also other benefits for users, such as savings due to preparing their own meals. Other benefits are likely in the coming years, including revenues associated with new commercialized products. These include the smart dummy, with a potential sales price of around \$8,000 apiece, and the new version of the bicycle ergometer, with a sales price to be determined following an upcoming round of tests. At the time of writing, the research team behind the bicycle ergometer was planning to soon file a declaration of invention with Université de Sherbrooke. The **non-pharmacological nutritional strategies for cognitive impairment project** has also contributed to the development of a new product. Based on Dr. Cunnane’s research results, Nestlé Health Science created a new formula with the same active ingredients in order to commercialize the kMCT drink. That drink went to market in October 2020 under the name BrainXpert Energy Complex. It is not yet available in Canada, but in 2020, Université de Sherbrooke (via TransferTech Sherbrooke) and Nestlé Health Science negotiated a licence and a patent for commercialization of the kMCT drink.

4.0 Summary and conclusion

This report presents the socioeconomic benefits of eight research projects funded by the CFI, the MEI and the FRQ in the Estrie region of Quebec, in the fields of aging and rehabilitation. The results show significant current impacts for the majority of projects, as well as very promising signs for the future.

Figure 3 gives a summary of the projects' impacts based on the data collected in this study. Namely, several students benefited from the research work, and funding contributed to the development of essential infrastructure for the research teams. The summary also shows the extent of project impacts outside academia. These research projects addressed fundamental issues for our seniors, including care, access to care, health and maintaining autonomy. Although the projects are still in development, several of them are already helping a number of seniors and their family caregivers to maintain their quality of life. Some have also had institutional and economic impacts, particularly in terms of efficiency. These impacts include both cost savings and a wider scope for intervention efforts, whether by postponing seniors' transition away from independence or by increasing the number of patients that care providers can serve.

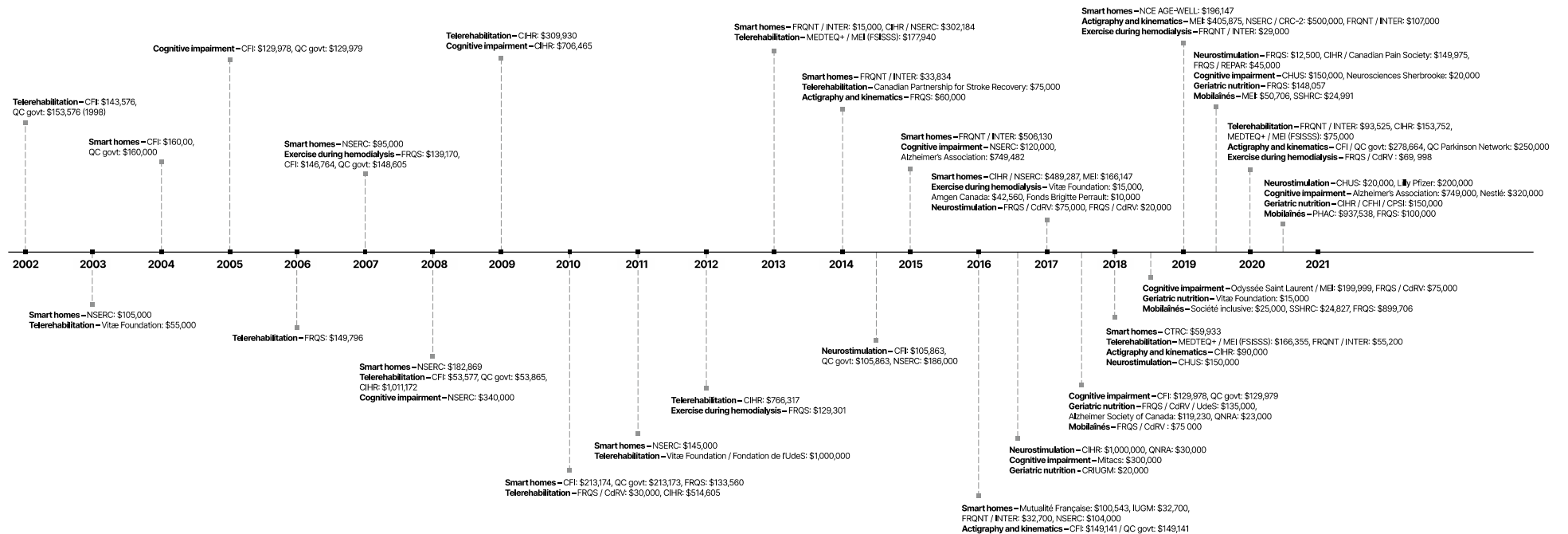
The projects' promising results give every indication that their impacts will grow over time. The technologies in question have now been proven, and the multidisciplinary teams now have established knowledge and skills, both within and beyond the university, that will only continue to develop. Barring dramatically unforeseen complications, future research seems likely to show an overall growth in these impacts and, consequently, great benefits for our seniors.

* * *

Figure 3: Summary of impacts

			SOCIAL IMPACTS	ORGANIZATIONAL AND ECONOMIC IMPACTS
		ACADEMIC RESEARCH	IMPACTS IN ACADEMIC SETTINGS	
FUNDING				
TOTAL (1998-2020):			Improved diet	Impacts on organisations and institutions in Estrie: <ul style="list-style-type: none"> ➤ Increased awareness of issues seniors face ➤ Better familiarity with local agents of change ➤ Connections created between various partners with no relationships prior to the project ➤ Improved services for seniors Economic impacts in Estrie and elsewhere in Quebec: <ul style="list-style-type: none"> ➤ Decrease in professional time ➤ Postponed transfer to intermediate resources or CHSLDs ➤ Decreases in medication use or care needed ➤ Jobs maintained ➤ Cost savings (health system and users) ➤ Revenue associated with intellectual property
➤ \$26.4 million	a. Smart homes	Laboratories created and laboratory research capacity improved	Improved care and treatment: less pain and better sleep	
➤ 95 grants	b. Telerehabilitation: TeraPlus telehealth platform project	Research groups created and collaborative projects launched	Better access to transportation	
DISTRIBUTION:	c. Actigraphy and kinematics of movement	Students trained and graduated	Continued ability to live independently at home	
➤ CFI/QC, FRQ & MEI \$10.3 million (39%)	d. Physical exercise during hemodialysis	29 Master's students participated in research work	Better quality of life and resumption of social activities	
➤ Federal \$12.6 million (48%)	e. Neurostimulation therapy	20 Doctoral students participated in work and/or did thesis work on related subjects	Impacts on younger populations dealing with similar issues	
➤ Foundations \$1.6 million (6%)	f. Non-pharmacological nutritional strategies for cognitive impairment	11 Post-doctoral fellows participated as part of research teams		
➤ Others \$1.9 million (7%)	g. Geriatric nutrition	9 Undergraduate interns participated in research work		
	h. Living laboratory and mobility: The Mobilaînés project	11 Research professionals participated in research work		
		Students and highly qualified personnel pursuing their careers in related fields		

Appendix A: Funding of cases



CdRV: Centre de recherche sur le vieillissement [Research centre on aging]
CFHI: Canadian Foundation for Healthcare Improvement
CFI: Canada Foundation for Innovation
CHUS: Centre hospitalier universitaire de Sherbrooke [Sherbrooke university hospital centre]
CIHR: Canadian Institutes of Health Research
CPSI: Canadian Patient Safety Institute
CRC-2: Canada Research Chair – Tier 2
CRIUGM: Centre de recherche de l'Institut universitaire de gériatrie de Montréal [IUGM Research Center]
CTRC: Canadian Traumatic Brain Injury Research Consortium
FRQNT: Fonds de recherche du Québec – Nature et technologies
FRQS: Fonds de recherche du Québec – Santé
FSISS: Fonds de soutien à l'innovation en santé et en services sociaux
INTER: Interactive technologies of engineering in rehabilitation
IUGM: Institut universitaire de gériatrie de Montréal
MEDTEQ+: Quebec Industrial Consortium for Research and Innovation in Medical Technology
MEI: Ministère de l'Économie et de l'Innovation (Québec) [Ministry of the economy and innovation]
NCE: Networks of Centres of Excellence
NSERC: Natural Sciences and Engineering Research Council of Canada
PHAC: Public Health Agency of Canada
Qc govt: Quebec government
QNRA: Quebec Network for Research on Aging
REPAR: Réseau provincial de recherche en adaptation-réadaptation [Quebec Rehabilitation Research Network]
SSHRC: Social Sciences and Humanities Research Council of Canada
UdeS: Université de Sherbrooke