Smart Environments in Support of Fragile and Isolated Older Adults: Protocol for the City of Côte Saint-Luc's Living Lab

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Abstract: In the context of an aging population, 5.6 million people in Canada are suffering from social isolation and this is a key factor contributing to frailty because it promotes the onset of cognitive impairment, depression, and dependency in older adults. The COVID-19 pandemic and the demands of social distancing have particularly affected older adults by increasing their exposure to social isolation and medical complications. In addition, the pandemic has highlighted the vulnerability of the health and social services system and the importance of exploring community involvement and telehealth solutions – such as telemonitoring activities of daily living (ADLs). This paper presents the protocol of a living lab project that aims to co-develop a support model around the telemonitoring of ADLs at the scale of a city, Côte Saint-Luc. In particular, the project seeks to optimize older adults' identification and use of resources available in the community. These resources include services from the city, the health and social services system, and community organizations, and support from families and community volunteers. With the support of telemonitoring, this ecosystem could enable seniors to live at home for longer.

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1 INTRODUCTION

As the population ages, the long-term sustainability of the health and social services system is becoming more precarious because chronic illness and functional loss usually lead to increased use of services. The health and social services system is struggling to meet demand and one in five older adults who use both formal and informal home care report unmet needs (Turcotte & Grant, 2006). In addition, the current COVID-19 pandemic has further strained the already limited resources, reducing access to health and social services. Indeed, day programs, ambulatory and home-based services were put on hold as professionals were deployed to other care roles deemed to be of higher priority (Koeberle et al., 2020).

The pandemic also exposed older adults to social isolation due to the lockdown and social distancing rules. Social isolation is a major problem in Western societies, with 5.6 million Canadians suffering from it (Angus Reid, 2019). This phenomenon is experienced as an objective and/or subjective reduction in the number and quality of interpersonal contacts which leads to a loss of an individual's social roles (Fakoya, McCorry & Donnelly, 2020). Social isolation is a key factor contributing to frailty, as it promotes the development of cognitive impairment, depression, and dependency, thereby creating a spiral that increases frailty status (Gobbens, 2016). Frailty is a condition of vulnerability that exposes older adults to incidental adverse events which leads to an increase in their use of health and social services (Abell & Steptoe, 2021; Andrew et al., 2018).

How can we help frail and isolated older adults better meet their needs to remain at home? The pandemic has highlighted the vulnerability of the health and social services system and the importance of better exploring both community involvement (Ministères des solidarités et de la santé, 2020) and telehealth solutions (Smith et al., 2020). Furthermore, the pandemic has exposed great deficiencies in the services provided to older adults in long-term residential care. This means that a more robust, system of home-based care provision is critical moving forward. More diverse partners need to be involved to put in place an ecosystem of support that is adapted to, and provided in close proximity to older adults, i.e., in their neighborhoods. It has become increasingly urgent to mobilize cities, community organizations, citizens, families, and older adults themselves in a process of reflection and co-construction of an ecosystem of support that will have a significant impact on the home support and older adults' quality of life.

In addition to having exacerbated social isolation, the pandemic led to the growth of telehealth, though some of its possibilities have yet been exploited. Among these possibilities, is the telemonitoring of activities of daily living (ADLs) to collect data remotely via smart environments in order to detect and analyze patterns of engagement in ADLs in a person's home over a long period of time; for example, detecting patterns of sleep, personal hygiene, meal preparation and outings. Our team has shown that these patterns, and their deviations when compared to the person's normal routine, can be used to better understand home service needs and to detect, and even predict, adverse events that could lead to hospitalizations or changes in living environments (Lussier et al., 2020a, 2020b). However, to our knowledge, this form of telemonitoring has not yet been tested on a large scale or integrated into a complex ecosystem that allows for interactions between multiple partners (health system, municipalities, community organizations, etc.).

This paper presents an ongoing, living lab project taking place in Côte Saint-Luc, a city located on the island of Montreal in Canada. The project uses a model of support grounded in telemonitoring of ADLs to optimize the identification and use of available community resources by frail and isolated older adults. These resources include city services, health and social services, and community organizations, and support from families and community volunteers. The paper will present the rationale of this study, including our past collaboration with the city of Côte Saint-Luc, as well as the potential of telemonitoring of ADLs to support older adults. It will also present our past studies on the topic. The paper concludes with a presentation of the protocol of the project that started in 2021 and will end in 2024.

1.1 History of Partnership with the City of Côte Saint-Luc

In 2017, Infrastructure Canada launched the Smart Cities Challenge competition, which challenged municipalities and Indigenous communities across Canada to use a smart city approach to address local issues for their residents. The City of Côte-Saint-Luc (34,066 residents) submitted a proposal that was selected as one of 10 finalists in the category of cities with 30,000 to 500,000 residents. With the help of our research team, the city wanted to ensure that its citizens were better connected to their community, to municipal services, and were more socially engaged through connected technologies. The Mayor, his team of councilors, and the City Manager were actively involved in this project. For eight months, the City led a broad community engagement campaign and, with our research team, conducted a pilot project to assess the feasibility of such an approach. In the fall of 2018, our team conducted eight focus groups with all of the City's stakeholders: city councilors, staff, frail older citizens, engaged older adults, families and caregivers, etc. In the homes of five older citizens, we also deployed assistive technologies, alongside an ADLs telemonitoring system that we developed through a previous research project (Ngankam et al., 2019), over a 4-month period. Ours results indicate that older citizens are isolated and are not able to obtain all the services they need to remain in their homes and that city services are not being used to their full potential. In addition, stakeholders noted that there is no systematic effort to screen or assess the needs of older citizens. Older citizens who received the technology found the experience very positive, experienced an increased sense of security, and expressed interest in obtaining information about their lifestyle via telemonitoring.

While the final proposal was unfortunately not selected by Infrastructure Canada, it laid the groundwork for a living lab, identified, and mobilized the necessary resources, and established a collaborative network to build on. Since this competition, the City of Côte Saint-Luc, which has one of the oldest populations in Canada, has been particularly affected by the COVID-19 pandemic. Thus, it seems more relevant and timelier than ever to set up a living lab in this City. With this project, the City and our team wish to continue the extraordinary mobilization of this community and to set up a Living Lab that meets the needs, expectations, and dynamism of this ecosystem. This project goes beyond the pilot project, which focused on monitoring ADLs, because it will contribute to a reassessment of the concept of frailty and will produce a complete analysis of the ecosystem of support in order to better address social isolation.

1.2 The Potential of Smart Homes for Home Support of Older Adults

Smart environments used in telemonitoring can play a key role in the provision of adequate home support services. In the context of this proposal, smart environments refer to "environments that adopt ICT to collect and share information, analyze and monitor residents' behavioral patterns, and improve their quality of life" (Lee & Kim, 2020). An "environment" in this proposal refers to a single house, apartment or other type of living situation that is not integrated into a care facility (such as an intermediate residence or a long-term care facility).

When integrated into a human chain of support, the smart environment can be more effective and focused on the needs of older adults. The social network of the older adult becomes an important part of this system and both systems (smart environment and social support) have the potential to decrease social isolation, prevent adverse events and thus promote care at the right time, and for the right person (Ngankam, Pigot, Frappier, Oliveira, & Giroux, 2017; Lussier et al., 2020a, 2020b). To achieve this, smart environments must be integrated into a complete ecosystem of services and care, supporting older adults according to their needs and preferences. Smart environments can, therefore, help develop a comprehensive support system for frail and isolated older adults at critical times; for example, if the telemonitoring system detects that the person has not been out of home for a certain amount of time, it can alert a neighbor, a member of the family or a person from the City services to go and verify that the older adult is well.

Over the years, several advances have been made in the field of telemonitoring of ADLs. Studies have shown the possibility of detecting mild cognitive impairment or even Alzheimer's disease based on simple markers such as walking speed (Akl, Taati, & Mihailidis, 2015; Kaye et al., 2012; Sperling et al., 2011) or time spent performing ADLs (Dawadi, Cook, Schmitter-Edgecombe, & Parsey, 2013; Lussier et al., 2019; Wu et al., 2021). In this regard, our recent review showed that cognitive deficits could be detected by the telemonitoring of general activity, outings, sleep patterns, and computer use (Lussier et al., 2019). Our team has further shown that social and health care providers can adapt their intervention plan according to detected events in daily life, such as time spent in inactivity, use of kitchen appliances, etc. [(Lussier et al., 2020; Lussier et al., 2020). Older adults can thus be offered more, or fewer, services depending on the needs detected.

Telemonitoring via smart environments holds great potential to optimize home support services (Lussier et al., 2020a; 2020b). In fact, in the last ten years, an increasing number of studies have been devoted to the development of such systems but have mainly been oriented towards the development and conceptualization of technological components. Very few of them go as far as including small-scale testing in a living laboratory context. In fact, recent literature reviews on the subject (e.g. Marikyan, Papagiannidis, & Alamanos, 2019; Queirós, Silva, Alvarelhão, Rocha, & Teixeira, 2015) indicate that less than 10%

of current studies include usability testing, and even fewer include field testing. As a result, little has been published on the implementation processes required to integrate telemonitoring into the social and health care system or the community (notably, in cities) via smart environments, including the facilitators and barriers to such implementation.

1.3 Past Work of Our Team

Our team developed NEARS, a telemonitoring platform of ADLs that is currently being tested in the health and social services system in Canada and in a residence for older adults. NEARS is based on environmental sensors and on a secure web-based platform that receives data from these sensors, processes it via activity recognition (AI) algorithms, represents this data in various forms (tables, figures) to users, and sends alerts as needed (Ngankam et al., 2017, 2019; Lussier et al., 2020a; 2020b). NEARS makes it possible to adjust the extent to which users need to interact with the system and the information they are given access to, according to their abilities. For example, it may be decided that an older adult should not need to interact at all with the system due to a limited ability to do so, in which instance the system would be used by his or her support ecosystem; or alternately a healthier older adult may want to interact with the system if he or she is comfortable with the technology. NEARS has been validated and deployed in accordance with the Québec Ministry of Health and Social Services' rules and regulations regarding data security and protection.

However, in these projects, the NEARS platform is used with only one type of actor at a time. The present project therefore aims to connect several actors of the ecosystem of support to the platform to avoid working in silos. In this project, the older citizens' ecosystem is thus conceptualized as a dynamic interaction between families, health and social service providers, community volunteers (e.g., neighbors), municipal services, community-based organizations, and research partners; entities that all have the well-being of frail older adults at the heart of their mission, but do not frequently work as an organized system in the city of Côte Saint-Luc, or most other cities. They will all collaborate in the co-design of the services surrounding the system.

1.4 Objectives of the City of Côte St-Luc's Living Lab

The general objective of this living lab is to reduce social isolation, improve safety and support aging-in-place using a smart environment installed in the home of older adults and integrated into a human ecosystem. The specific objectives are as follows: (1) To co-construct a social infrastructure composed of a close network established between the different partners, namely the City, health and social services, neighborhood organizations, research community, older citizens and their families; (2) To develop an in-depth understanding of the interactions between the different actors of the older adults' ecosystem in order to conceptualize a support model articulated around sustainable smart environments that are adapted to the needs of all partners; (3) To co-develop the support ecosystem and determine the best ways of implementing it; (4) To deploy a citywide project and evaluate its usability; (5) To identify the facilitators and obstacles to implementation of the system, in order to make necessary changes that ensure its sustainability in the neighborhood and enable the reproduction of the initiative on a larger scale.

2 METHODS

2.1 Study Design

For this project, a living lab is defined as an ecosystem made up of numerous stakeholders of differing perspectives, all of whom contribute towards a shared objective through their co-construction of a social and technological innovation (Dubé et al., 2014). The living lab approach has the best fit to this project. Indeed, the social isolation of older adults is a complex and multidetermined problem, and the person's entire ecosystem is responsible for putting in place conditions to promote home care services. In addition, a project in close collaboration with the community makes it possible to observe phenomena that are difficult to recreate or study in a controlled research laboratory context, such as real interactions between stakeholders. The living lab approach also allows us to go beyond the traditional one-way approaches to knowledge transfer; it favors the development of innovations by and for the community so that these innovations have real and long-term impacts.

Considering the relationships established with the community and the objectives pursued by the program, an action design research method (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011) is used within the living lab. This method is the most relevant, since the project's objectives require a major commitment from the main stakeholders, the co-development and co-planning of a social and technological innovation, as well as the need to follow an iterative process, i.e., a cyclical improvement of the innovations as they are implemented in collaboration with all the stakeholders involved (Koshy, Koshy, & Waterman, 2010). In this method, collaborators are actively involved in decision-making, with power shared between community stakeholders and the research team (Darses & Reuzeau, 2004). The aim of this method is to develop innovations "with" people, not "for" people.

Action design research includes six steps (Sein et al., 2011): 1) formulation of the problem and its clarification; 2) co-development of the innovation with a user-centered design approach; 3) implementation of the solution; 4) evaluation; 5) reflection on the process; and 6) sharing of the results with all stakeholders.

2.2 Setting

2.2.1 Preliminary Step: Setting up the Living Lab Governance Structure

Before starting the project, the organizational structure of the living lab and how it will function (Dubé et al., 2014) must be set up in a collaborative manner with representatives of all stakeholders. This step consists of setting up various committees and working groups, each with a specific mission in the living lab. Each stakeholder can play the desired role according to his or her availability and skills. This step was started in June 2021 and should be completed by the end of January 202e.

As this project is an action design research project, all stakeholders are involved in all the important stages of the project. The team is composed of both researchers and community partners, ensuring a two-way knowledge transfer throughout the project and the successful implementation of the digital solution. These partners are currently the City of Côte Saint-Luc, represented by the Mayor of the City. However, City Councilors and the General Director, all of whom have been involved in all discussions on this project since 2018, will continue to be involved during the deployment of the project through an advisory committee composed of a representative of all partners. This involvement will be complemented by other members of the administration, according to their field of expertise (e.g., the person in charge of emergency services). Thus, depending on the committees and working groups set up (e.g., working group on the co-design of the service, working group on usability tests, working group on the recruitment of isolated older adults, etc.), the City will be able to delegate the best person to contribute to the discussions and ensure a harmonious implementation of the system in the municipal services. We also have a close partnership with the CIUSSS West Central Montreal (a health and social services institution), whose territory includes the City of Côte-Saint-Luc. Stakeholders will take part in the activities according to their expertise, within the relevant working groups (e.g., co-design of the service).

2.2.2 Step 1: Clarify the Problem

The problem clarification stage aims to better understand the role of each actor, including the smart environment, and to make it explicit through co-design workshops with the following key players: older citizens and their family, community organizations working with older adults, municipal employees and councilors, and health and social services professionals and their managers. The co-design workshops will consist of two to five activity sessions and will include a care mapping technique. These sessions will make it possible to clarify and map the relationships between stakeholders in an interactive and dynamic way, the role they play and wish to play in the digital environments, the potential facilitators and barriers to the implementation of smart environments, etc. An analysis of the data from each workshop will be carried out using mapping (Miles, Huberman, & Saldana, 2014).

2.2.3 Step 2: Co-development of the Innovations

This stage aims to co-develop the ecosystem of support to include smart environments. The collaborative approach will allow us to: 1) develop an innovation that fits harmoniously with the services and know-how already in place; and 2) meet the specific needs of all identified users to ensure its maximum adoption. The collaborative approach thus makes it possible to create a user-centered service. In this stage, 2 to 3 co-design workshops are planned. The form of these workshops is to be specified with the partners of the living lab. The deliverable of this step is the identification and formalization of who will play what role at what time, who will receive what information, and who will respond in what way. Ethical and privacy issues will be addressed in this step and will be treated as requiring careful address throughout the project. For example, ethical concerns impacting adoption and use of smart homes such as privacy, informed and supported decision-making, stigma, discrimination, and equity of access will be addressed.

For telemonitoring, we will use NEARS. The co-design workshops will determine the level of interaction or investment expected from each type of user. The co-developed support ecosystem around the telemonitoring will be pre-tested in a research lab setting with the various stakeholders to determine its clarity and usability (effectiveness, efficiency, and user satisfaction) as well as its acceptability. Participants will be asked to perform various tasks with the prototype, including receiving and responding to alerts. Different questionnaires will be used to measure satisfaction (system usability scale (Brooke, 1996) and user experience (Schrepp, Hinderks, & Thomaschewski, 2014), and a personalized questionnaire will be used to document general impressions of the developed service will also be employed. Objective measures will be taken to evaluate effectiveness and efficiency (degree of task completion, connectivity of the self-help network, number of interventions and contacts, etc.). Notes will be taken on user comments and feedback, and all of this data will be used to identify problems with the use of the prototype being tested. Acceptability will be measured by means of questionnaires [TAM2; Venkatesh, Morris, Davis, & Davis, 2003), UMUX (Finstad, 2010)].

Following the laboratory pretest, a validation of the acceptability and feasibility of the support service will be done. In this part of our usability test, we will evaluate how the formal and informal networks react to various immersive situations simulated in the homes of older adults and in organizations. Without being in a real situation, this task will be used to get as close as possible to a situation of real use of the system from the point of view of the different stakeholders.

2.2.4 Steps 3 and 4: Implementation and Evaluation of the Service

Implementation refers to the process used to integrate the co-developed service in the community. The implementation phase makes it possible to measure the barriers and facilitators to ensure that the implementation is successful. Implementation strategies will be planned within the working groups, including the identification and recruitment of frail and isolated older adults.

The project will collect mixed data, integrating a pragmatic pretest/posttest and an embedded single-case study (Yin, 2011). The main single case being the City of Côte Saint-Luc and sub-cases each household receiving the technology. We aim to recruit 20 older citizens who live alone, have a limited social network, low mobility, and come from different cultural communities. There will be no control group given the exploratory nature of the project and its complexity. The older adults will be recruited through the project partners. Quantitative impact measures will be identified with stakeholders, but could include the following measures: Social isolation measured with the Medical Outcome Study Support Survey (MOS-SS) score (Sherbourne & Stewart, 1991), and number of visitors, supplemented by semi-structured interviews of approximately 45 minutes; overall frailty status [e.g. mild, moderate, severe; Clinical Frailty Scale (Rockwood et al., 2005)], health-related quality of life (EuroQoL52) (Brooks & De Charro, 1996) and number and nature of adverse events encountered, such as hospitalization and change in living situation.

For the qualitative part of the project (embedded case study), we will comprehensively and integratively describe "how" and "why" (Yin, 2011) the support network is integrated around the telemonitoring and how it impacts social isolation and safety at both a macro (sites) and micro level (20 older citizens and their ecosystem). The City of Côte Saint-Luc will serve as the macro-level case. At the micro level, we will recruit 20 quartets consisting of 1) an older citizen, 2) their family caregiver, if possible,_3) the designated social and health care provider, and 4) a designated alert responder (e.g., workers from community organizations or volunteers); for a total of 80 participants. These quartets are considered the integrated subunits of analysis in the case. The quartet will be interviewed at three-time points before, during, and three months after service implementation. We may need to make iterative changes to the service over the course of the project to better align with the needs of the community. As for the results of the questionnaires, depending on the type of scale, these results will be analyzed with non-parametric or parametric statistical tests such as ANOVA.

2.2.5 Steps 5 and 6: Reflecting on the Process and Sharing Results

At the end of the pilot, we will meet again with all the partners involved, to complete a process evaluation. This postmortem will allow us to identify the effective and ineffective implementation strategies as well as facilitators and barriers to the implementation of a service around telemonitoring of ADL and the living lab as a whole, the strengths and limitations of the approach used, and the elements that could be addressed in the future. We aim to create an implementation guide to facilitate future deployment in other municipalities.

3 RESULTS

This project was funded by the Fonds de la recherche du Québec – Santé in June 2021. The Ethical Review Board (ERB) of the CIUSSS West-Central Montreal reviewed the protocol and provided approval for step 1. The ERB will review the other steps in a next round of evaluation, before their implementation. No research will be conducted without the proper ethical approval.

4 DISCUSSION AND CONCLUSION

This project aims to address two important problems encountered worldwide in western societies: older adults' home care - often approached in a reductionist and siloed manner - and social isolation, which is sometimes reduced to its social determinants. By addressing social isolation in interaction with health and novel technologies, this project is particularly innovative. Also, developing a living lab on a city scale is an exciting approach that will develop new methods of engagement between communities and research. It is essential, in this type of project, that local knowledge be recognized and integrated at all stages, allowing this project to go beyond the simple model of scientific experts (the researchers) to a partnership model (research experts and local experts - i.e., the community and its knowledge of the environment and its reality). As the community has been involved since the project's inception, we hope to have a rapid and direct impact on the relationships between the various stakeholders in the community capable of triggering a "snowball effect", i.e., the organizations working closely through the project will want to continue the collaboration and continue to be involved in activities that have a strong potential to decrease the social isolation of older adults in the long-term.

The creation of a living lab will allow for the development of new social and technological innovations because they will be carried out in close collaboration with local people. The meeting of these two milieus (research and field) will also make it possible to document the entire process surrounding this type of project and thus facilitate the transfer of the knowledge and methods developed through this partnership. This program will also be able to highlight new knowledge on the various factors involved in social isolation and their interrelationships, along with the junction of approaches used in health, human and social sciences, and technology. This will lead to a more accurate understanding of these multiple determinants.

In conclusion, we hope that the project will lead the citizens of the City of Côte Saint-Luc and its organizations to mobilize to change their vision of home care and social isolation of older adults, by working in an integrated manner. Future work will allow for a more large-scale deployment of the technological solution, evaluation of its cost-effectiveness metrics and regulatory approvals.

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