

Co-development and Deployment of a System for Telemonitoring of Activities of Daily Living in Older Adults Receiving Home Care Services: An Action Design Research Protocol

Maxime Lussier, Mélanie Couture, Sylvain Giroux, Aline Aboujaoudé, Hubert Kenfack Ngankam, Hélène Pigot, Sébastien Gaboury, Kevin Bouchard, Carolina Bottari, Patricia Belchior, Guy Paré, Nathalie Bier

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Table of Contents

Original Manuscript..... 5

Supplementary Files..... 42

 Multimedia Appendixes 43

 Multimedia Appendix 1..... 43



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Maxime Lussier^{1, 2*} PhD; Mélanie Couture^{3, 4*} PhD; Sylvain Giroux^{5*} PhD; Aline Aboujaoudé^{1, 2*} MSc; Hubert Kenfack Ngankam^{5*} PhD; Hélène Pigot^{5*} PhD; Sébastien Gaboury^{6*} PhD; Kevin Bouchard^{6*} PhD; Carolina Bottari^{2*} PhD; Patricia Belchior^{1, 7*} PhD; Guy Paré^{8*} PhD; Nathalie Bier^{1, 2*} PhD

¹Centre de recherche de l'Institut universitaire de gériatrie de Montréal Montreal CA

²École de réadaptation, Faculté de médecine Université de Montréal Montréal CA

³School of Social Work Université de Sherbrooke Sherbrooke CA

⁴Centre for Research and Expertise in Social Gerontology Integrated Health and Social Services University Network for West-Central Montreal Côte- Saint-Luc CA

⁵Faculty of Sciences and Faculty of Medicine and Health Sciences Université de Sherbrooke Sherbrooke CA

⁶Department of Mathematics and Computer Science Université du Québec à Chicoutimi Chicoutimi CA

⁷School of Physical and Occupational Therapy Faculty of Medicine, McGill University Montreal CA

⁸Research Chair in Digital Health, HEC Montréal Montréal CA

*these authors contributed equally

Corresponding Author:

Maxime Lussier PhD

Centre de recherche de l'Institut universitaire de gériatrie de Montréal

4545 Queen Mary Road

Montreal

CA

Abstract

Background: The Canadian government and its provincial counterparts consider home care a top priority, and home care services are looking for ways of optimizing their limited human and financial resources to offer the right services, at the right time. Telemonitoring of activities of daily living (ADL) holds great promise for better understanding the home care needs of older adults with cognitive decline, especially those who live alone. Therefore, it could support the delivery of better-targeted services for this population.

Objective: This article presents the research protocol of the SAPA project, designed to document the potential of ADL telemonitoring as a support tool for home care clinicians working with older adults within the Canadian public healthcare system. The project's three main objectives were to: (1) Co-develop an ADL telemonitoring system that meets the requirements of key stakeholders; (2) Implement the system and identify specific use cases; (3) Identify factors that could promote its long-term use in a real-world setting.

Methods: An action design research (ADR) project was conducted. It consisted of a four-stage research process including 1) problem formulation; 2) building, intervention, and evaluation in the real context of home care services; 3) reflection and learning; and 4) formalization of learning. This project consisted of two cycles of development (alpha and beta) that involved cyclical repetitions of stages 2 and 3 to develop a telemonitoring system of ADL. Stakeholders were included in each co-development cycle, among them healthcare managers, clinicians, older adults and their family. Qualitative and quantitative data were collected throughout the project.

Results: A first iterative cycle, the alpha cycle, took place from early-2016 to mid-2018. A first prototype of an ADL telemonitoring system was deployed in the homes of four care recipients receiving home care services through one public health institution. The prototype was used to collect data about the care recipients' ADL routine. The data were used by clinicians to support their home care intervention plan and results are presented here. The prototype was successfully implemented and perceived as useful, although obstacles were encountered. Likewise, a second co-development cycle (beta cycle) took place in three public health institutions from late-2018 to late-2022. The telemonitoring system was installed in 31 care recipients' homes

and detailed results will be presented in future papers.

Conclusions: To the best of our knowledge, this is the first reported ADR project in ADL telemonitoring research including two iterative cycles of co-development and implementation embedded in real-world clinical settings of a public health system. The SAPA project will provide extensive documentation of use cases and factors that either facilitate or restrict the implementation of an ADL telemonitoring system.

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Original Manuscript

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Abstract

(450/450 words max)

Background: Telemonitoring of activities of daily living (ADL) offers significant potential for gaining a deeper insight into the home care needs of older adults experiencing cognitive decline, particularly those living alone. This approach holds the promise of facilitating the provision of more targeted services. In 2016, our team and a healthcare institution in Montreal sought to test this technology to enhance the support provided by home care clinical teams for older adults facing cognitive deficits and residing alone. It was within this context that the SAPA project was initiated, embracing an innovative research approach combining action research and design science.

Objective: This article presents the research protocol of the SAPA project, facilitating the replication of similar initiatives in the future. The primary objectives of the SAPA project were to: (1) Co-develop an ADL telemonitoring system aligned with the requirements of key stakeholders; (2) Deploy the system in a real clinical environment to identify specific use cases; (3) Identify factors conducive to its sustained use in a real-world setting. Given the context of the SAPA project, the adoption of an Action Design Research (ADR) approach was deemed crucial. ADR is a framework for crafting practical solutions to intricate problems encountered in a specific organizational context.

Methods: This project consisted of two cycles of development (alpha and beta) that involved cyclical repetitions of stages 2 and 3 to develop a telemonitoring system of ADL. Stakeholders were included in each co-development cycle, among them healthcare managers, clinicians, older adults and their families. Qualitative and quantitative data were collected throughout the project.

Results: A first iterative cycle, the alpha cycle, took place from early-2016 to mid-2018. A first prototype of an ADL telemonitoring system was deployed in the homes of four care recipients receiving home care services through one public health institution. The prototype was used to collect data about the care recipients' ADL routine. The data were used by clinicians to support their home care intervention plan and results are presented here. The prototype was successfully deployed and perceived as useful, although obstacles were encountered. Likewise, a second co-development cycle (beta cycle) took place in three public health institutions from late-2018 to late-2022. The telemonitoring system was installed in 31 care recipients' homes and detailed results will be presented in future papers.

Conclusions: To the best of our knowledge, this is the first reported ADR project in ADL telemonitoring research including two iterative cycles of co-development and deployment embedded in real-world clinical settings of a public health system. We discuss the artifacts, generalization of learning, and dissemination generated by this protocol in the hope of providing a concrete and replicable example of research partnerships in the field of digital health in cognitive aging.

Keywords: Action design research; Protocol; Activities of daily living; older adults; cognitive deficits; telemonitoring; public health-care system; home care services.

Authors:

Maxime Lussier PhD^{a, b}, Mélanie Couture PhD^{c, d}, Sylvain Giroux PhD^e, Aline Aboujaoudé MSc^{a, b},

Hubert Kenfack Ngankam PhD^e, H  l  ne Pigot PhD^e, S  bastien Gaboury PhD^f, Kevin Bouchard PhD^f, Carolina Bottari PhD^b, Patricia Belchior PhD^{a,g},
Guy Par   PhD^h and Nathalie Bier PhD^{a,b}

^aCentre de recherche de l'Institut universitaire de gériatrie de Montréal, Montréal, Québec, Canada

^bÉcole de réadaptation, Faculté de médecine, Université de Montréal, Montréal, Québec, Canada

^cCentre for Research and Expertise in Social Gerontology, Integrated Health and Social Services
University Network for West-Central Montreal, Côte- Saint-Luc, Québec, Canada

^dSchool of Social Work, Université de Sherbrooke, Sherbrooke, Québec, Canada

^eFaculty of Sciences and Faculty of Medicine and Health Sciences, Université de Sherbrooke, Sherbrooke, Canada

^fDepartment of Mathematics and Computer Science, Université du Québec à Chicoutimi, Chicoutimi, Québec, Canada

^gSchool of Physical and Occupational Therapy, Faculty of Medicine, McGill University, Montreal, Quebec, Canada

^hResearch Chair in Digital Health, HEC Montréal, Montréal, Québec, Canada

Corresponding author: lussier.maxime@gmail.com



Co-development and Deployment of a System for Telemonitoring of Activities of Daily Living in Older Adults Receiving Home Care Services: An Action Design Research Protocol.....	1
Abstract.....	1
Introduction.....	6
Telemonitoring of Activities of Daily Living.....	6
Context and Aim.....	7
Methods.....	9
Background.....	9
Problem Formulation.....	9
Building, Intervention, Evaluation (BIE).....	10
Building.....	10
Intervention.....	11
Evaluation.....	11
Characteristics of Participants and Demands for ADL Telemonitoring.....	13
Clinicians who identified a care recipient and wished to participate filled out a request form detailing their demands for telemonitoring, the reasons that led them to request remote monitoring for this care recipient and which ADL they would like to obtain more information about via telemonitoring. Through interviews, they were also asked about facilitators and barriers to home care for this specific care recipient. After receiving the form, a research assistant called the clinician to provide any further details or clarifications as needed.....	13
Usage and Benefits of ADL Telemonitoring.....	13
Facilitators and Barriers to ADL Telemonitoring Deployment.....	13
Ethical Considerations.....	14
Results.....	14
Reflection and learning.....	14
Usage and Benefits of ADL Telemonitoring.....	14
Facilitators and Barriers of ADL Telemonitoring Deployment.....	15
Beta Cycle.....	15
Methods.....	15
Building, Intervention, Evaluation (BIE).....	15
Building.....	16
Evaluation.....	17
Characteristics of Participants and Demands for ADL Telemonitoring.....	17
Usage and Impact of ADL Telemonitoring.....	18
Facilitators and Barriers to ADL Telemonitoring Deployment.....	18
Usability and Acceptance of ADL Telemonitoring.....	18
Cost Estimation of ADL Telemonitoring.....	18
Ethical Considerations.....	19
Results.....	19

Reflection and Learning.....	19
Identification of Artifacts.....	19
Generalization of Learning.....	20
Dissemination.....	21
Conclusion.....	21
Abbreviations.....	22
References.....	23
Characteristics of care recipients:.....	30
With the care recipients' consent, access to medical records was granted from January 2016 until the end of the participation. These data were extracted:.....	30
Characteristics of subunits.....	31
Documenting the implementation.....	31

Introduction

In Canada, it is estimated that two million people, or 5.4% of the total population, are active users of publicly funded home care services, with more than half of them being 65 years and older [1, 2]. Home care is considered a priority by the Canadian government and its provincial counterparts [3] [3]. In the province of Quebec, a predominantly French-speaking province in Eastern Canada, the Ministry of Health and Social Services has promoted aging in place since 2003, through a policy known as “Home Support: Always the Option of Choice” (“*Chez soi: Le premier choix*”) [4][4]. Despite this policy, 40% of older Quebec adults living with disabilities report unmet home care needs [2][2], which have been attributed to factors such as the lack of funding, difficulties in recruiting and retaining home care staff, and the increase in care needs in an aging population [5, 6][7][6][7]. These challenges, exacerbated since the COVID 19 pandemic, have led to urgent calls in Canada as well as in other countries to better support home care [6, 7].

The presence of cognitive deficits is an important risk factor for the loss of functional autonomy [8, 9] and is associated with important needs for home care support services [6][6]. Older adults with cognitive decline, such as those diagnosed with Alzheimer’s disease, are progressively dependent on others for both instrumental and basic activities of daily living (IADL and BADL), which increases the stress and burden on caregivers (families and relatives) and social and healthcare services [10, 11][8, 9]. Everyday memory losses and difficulties identifying and recognizing their own difficulties affect the ability to recall and report on events, including how they are managing their ADL [10, 11]. These individuals may also put themselves at risk by engaging in behaviors that are dangerous to their health and safety, in particular when they live alone (e.g., falls, kitchen fires, medication non-compliance) [16][12].

Progressive cognitive decline and its impact on ADL therefore limits the ability of health and social services to rely on these patients to better understand their home care service needs. This uncertainty can significantly impact intervention plans and resource management. [17, 18] On the one hand, this may lead to the costs of some care recipients’ needs not being covered by public care services due to a lack of supporting evidence, and, on the other hand, some services may be offered although they are unnecessary because of clinicians’ need to create contingencies to address potential risks [13, 14].

In this context, we propose that a key strategy to better understand the needs of older adults with cognitive decline and optimize available human and financial resources lies in the use of digital health technologies, and in particular, telemonitoring of IADL and BADL – hereafter referred to as *ADL telemonitoring*.

Telemonitoring of Activities of Daily Living

ADL telemonitoring is a form of remote monitoring and, as such, a component of telehealth. It is generally used to acquire proxy information about several factors or outcomes relevant to the home care support of older adults, such as functional independence, cognitive state, mobility, risk of falls and urinary tract infections [15-18]. The information is based on data collected via several sensors, such as wearable, ambient sensors (e.g., motion detectors, contact sensors), Radio-Frequency IDentification (RFID) and Global Positioning System (GPS) [23][19]. The resulting portrait of the person is based on information collected regarding their behavior in the home over the course of one or several days, such as entering and leaving a room, opening and closing kitchen cupboards, home entrances and exits, use of small electrical appliances, etc. Various algorithms can be used to recognize and classify ADL, including hidden Markov models, linear discriminant analysis, support vector machines, artificial neural networks, or adaptive network fuzzy inference system [24][20].

ADL telemonitoring can be used in the context of naturalistic scenario-based assessments in which participants are invited to a research lab apartment designed to simulate real-life situations. There, participants are usually asked to perform several scripted ADL, such as cooking a meal, cleaning the apartment, or booking a reservation [21-24].

ADL telemonitoring can also be used in the context of real-life assessments in which participants are asked to continue their daily routine while sensors are installed directly in their homes to collect data on sleeping habits, meal preparation, hygiene, mobility in the home, periods outside the home, and so on [29, 30][25, 26]. Over time, deviations from previous patterns can be detected and used to assess the ability of an older adult to live independently in the community and to detect potential future critical situations [27-30].

ADL telemonitoring thus seems very promising to better understand the needs of older adults with cognitive decline, in particular those living alone, in terms of ADL functioning and home care services requirements. Indeed, research in the area of ADL telemonitoring has been expanding over the last 20 years. In a recent umbrella review, Tannou et al. identified more than 191 experiments in the field and 17 reviews published to date [31]. Despite this dynamism, there is still little available evidence on the effectiveness of ADL telemonitoring and strategies for integrating it successfully in healthcare systems [31]. Most studies have reported data on prototypes and very few large-scale deployment studies have been conducted. There is therefore an important need for more in-depth studies on this subject.

Context and Aim

In 2016, we were approached by a health institution in the city of Montreal, more specifically by the director of the *Support for Seniors' Autonomy* program (*Soutien à l'Autonomie des Personnes Âgées* – SAPA, in French). SAPA programs aim to support older adults and meet their physical, psychological and gerontopsychiatric needs both in the community and during hospital stays. The director was searching for innovative ways to support homecare clinical teams to better address the needs of older adults with cognitive deficits who live alone. The directorate was also looking for solutions to optimize the use of limited human and financial resources in order to offer the right service, at the right moment. Our team and the top management team decided to engage in a joint research project on ADL telemonitoring, which became the “SAPA Project”. The global objectives of the SAPA project were to: (1) Co-develop an ADL telemonitoring system that addresses the needs of all key stakeholders; (2) Deploy the system in a real-world clinical setting and identify the specific use cases; and (3) Identify factors that could contribute to ensuring its long-term use in a real-world setting. To foster the project's success, we engaged with all key stakeholders involved in public home care services for older adults with cognitive deficits. We considered that to ensure optimal use and adoption of technologies by the healthcare community, it would be crucial to identify existing solutions, or create novel solutions, that address the specific needs of all key stakeholders, including the care recipients themselves [32]. To do so, stakeholders had to be involved in every step of the project in order to align their needs with the technology [33].

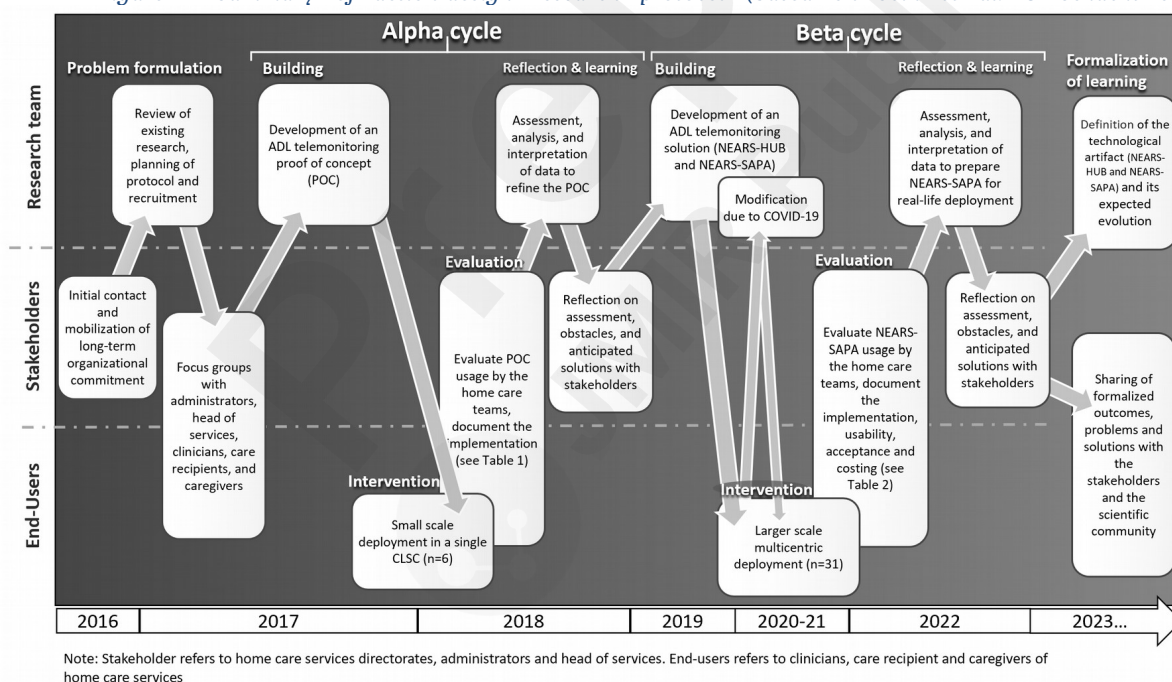
Considering the context of the SAPA project, the use of an Action Design Research (ADR) approach was identified as crucial. ADR provides a framework for developing practical solutions to complex problems encountered in a specific organizational setting. It is an iterative process that involves collaborations between researchers, practitioners, and stakeholders in designing, [38]deploying, and

evaluating interventions that improve the outcomes of a particular problem or issue [34]. This four-stage research process includes: 1) problem formulation; 2) building, intervention, and evaluation 3) reflection and learning; and 4) formalization of learning. ADR proposes the use of multiple cycles of development leading to cyclical repetitions of stages 2 and 3. Carried out in collaboration with the stakeholders (co-development process), these cycles allow refinement of the technology and related interventions to be implemented subsequently in a real-world setting. The SAPA project underwent two iterative technological design cycles, entitled “alpha” and “beta” cycles. The alpha cycle took place from early-2016 to mid-2018 and the beta cycle from late 2018 to late 2022.

A key feature of the SAPA project was its novel methodological approach. In this paper, we present the SAPA research protocol and its various co-development and deployment phases for the two cycles of ADR. To our knowledge, this represents the first detailed publication of a methodological framework in this field of research. Taking the initiative to share a research design makes it possible to be more transparent about the methodologies used, as well as to provide an in-depth explanation of the process so that it can be reproduced in the future. It also provides a description of a concrete example of research partnerships in the field of digital health in cognitive aging.

In the following sections, we will present each cycle and stage of the projects, which involves multiple research methods as recommended by action research methodologists [35]. Specific methodological details are presented in Appendix 1. Figure 1 presents an overview of the project’s timeline and key elements for each cycle and stage.

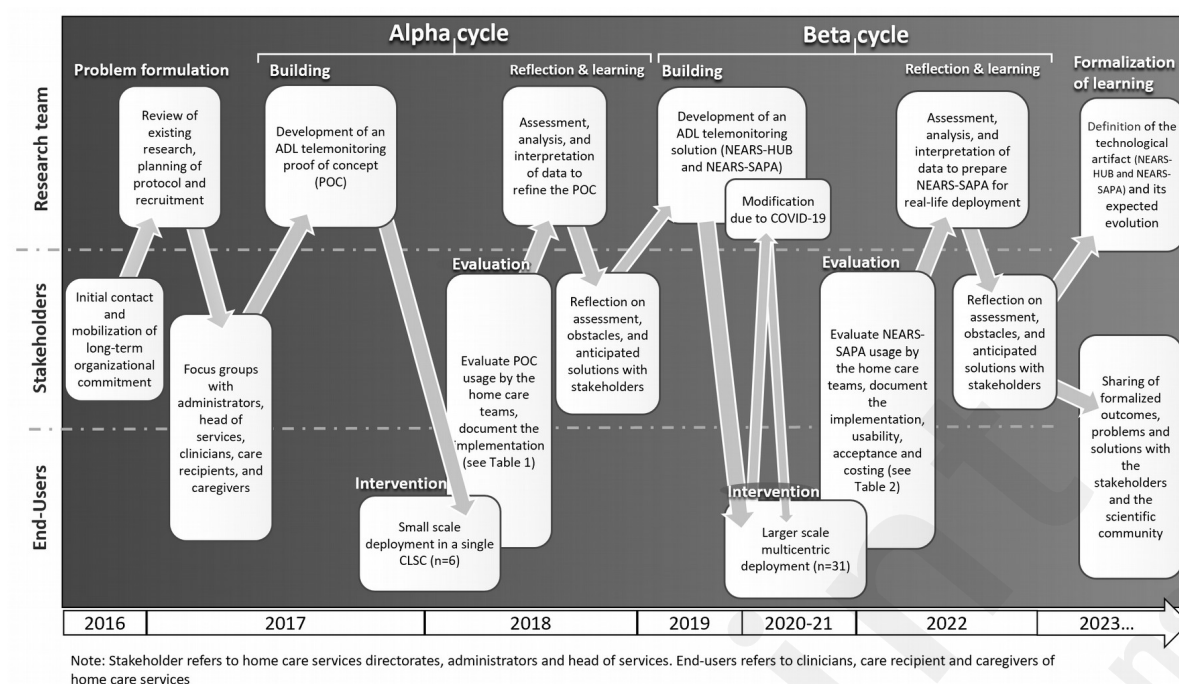
Figure 1 Summary of action-design research protocol (based on Sein et al. & Schacht et al. [34, 36])



Alpha

cycle[38,

40]



Methods

Background

The SAPA project aimed to provide an in-depth understanding of the potential of ADL telemonitoring in the specific context of the Canadian public healthcare system, and in particular in the Province of Quebec. This Province has an estimated population of 8.3 million, residing in 18 administrative areas referred to as health regions. For a given health region, all public health and social service institutions are networked into integrated health and social service centers (CISSS) or university health and social services centers (CIUSSS) when located in an area where a university offers an undergraduate medical training program or has a university institute in the social services field. These administrative entities are responsible for delivering care and services to the population of an assigned territory via hospitals, residential and long-term care establishments, rehabilitation centers, child- and youth-protection centers, as well as local community service centers (CLSC). CLSCs offer front-line health and social services, including home care through dedicated programs.

The alpha cycle of the SAPA project was conducted within the CSLCs' clinical services of one CIUSSS of the city of Montreal.

Problem Formulation

The alpha cycle started with a problem formulation stage aimed at conceptualizing the research problem, securing long-term organizational commitment, and clarifying roles and responsibilities with stakeholders. This stage combined theoretical knowledge and experiential knowledge informed by real-life practices [38][34]. As previously mentioned, the initial problem (i.e., the need to support home care clinical teams in meeting the needs of older adults with cognitive difficulties living alone in the community) was brought to the research team by the health institution.

To arrive at a mutual understanding of the problem and prioritize potential technological solutions at the start of the project in late 2016, a descriptive qualitative method was followed [41][37]. More specifically, individual interviews and focus groups were conducted with key stakeholders (administrators, head of services, clinicians, older adults and caregivers; n=23 in total) of one

specific sector/CLSC of the CIUSSS 1 (for more details, see Appendix 1 – section 1, as well as Couture et al. [42][38]). This sector was chosen by the head administrator as the most appropriate site for project deployment. Participants were questioned on the levers and obstacles to home care of older adults and technology usage within this context. At that time, neither the researchers nor the clinical team had a specific technology in mind to address the problem. However, to support the reflection process, several technological solutions were presented to the clinical teams. These included assistive devices and monitoring technologies such as smart home sensors, smart calendars, pill distributors, serious games, and stove safety devices.

One of the main findings was that administrators and clinicians thought that monitoring technologies could help them obtain more objective and reliable information to support their decision-making process in order to develop an adapted intervention plan with the care recipients [42, 43][38, 39]. More precisely, they wanted a technology to support their assessment and management of the risks involved in maintaining care recipients at home as long as possible. A second finding was that stakeholders insisted on avoiding the usage of cameras or microphones to preserve intimacy/confidentiality [42, 43][38, 39]. They also wanted to avoid wearable technologies, as older adults with cognitive deficits would likely forget to wear them. Finally, it was mentioned that an unobtrusive technology, requiring little involvement on the part of the older adults, would be the most likely to be successfully implemented.

Considering these expectations, ADL telemonitoring seemed to be the most promising technology to fully address the needs expressed by all. At the time of the study, there was no such system available on the market and ready to be deployed in a home care setting. We therefore resolved to design a system specifically for this research project, based on our previous work [21, 28, 44-48][17, 24, 40-43]. With the stakeholders' approval of the project scope and vision, we secured a long-term organizational commitment as well as funding for the subsequent phases.

Building, Intervention, Evaluation (BIE)

In the second stage of ADR, the initial design of the technological artifact is generated using the problem framing adopted in the first stage [38][34]. The BIE phase, which is an iterative process conducted in the target environment, involves building the technological artifact, intervening in the organization, and evaluating the outcomes. The product of this stage is the design of the artifact.

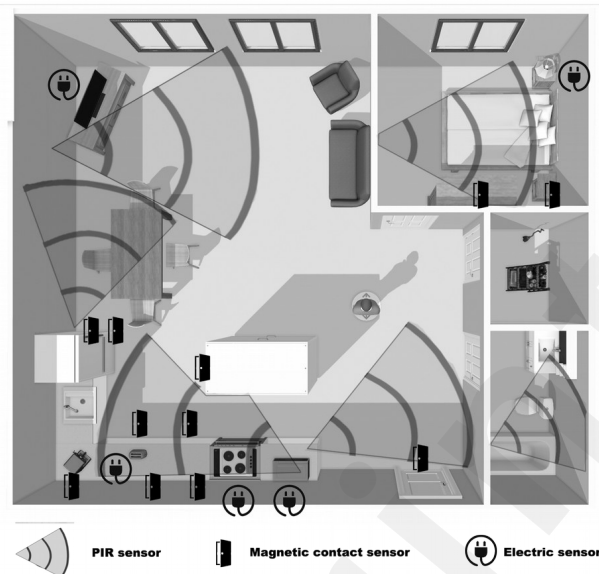
At this point of the alpha cycle, the overall target and goal of knowledge generation was to design and create an ADL telemonitoring system to support clinicians' decision-making process related to risk management. As is often the case in information technology-dominant artifact creation, we opted to develop a Proof Of Concept (POC) that could be quickly developed and tested in the homes of a small sample of older adults receiving home care services (i.e., alpha cycle). POC versions are formative and can help to validate several anticipated and unanticipated outcomes of technology usage and deployment [38][34]. Early designs serve as lightweight interventions in a limited organizational context.

Building

For the POC, we used a lightweight sensor infrastructure, comprising four non-intrusive, low-cost, wireless devices similar to the one deployed by Caroux et al. [49][44]. With their consent, sensors were deployed in each participating patient's home: passive infrared (PIR) sensors, magnetic contact sensors, smart electric switches, and water sensors. Sensors were paired to an IoT device, the VeraPlus Z-Wave Home Controller™, which served as the data collection point (i.e., a controller). Sensors were positioned in each home so as to capture data on ADL including sleeping, cooking, showering and leaving the home (Figure 2). For more details on each sensor's role, see Appendix 1 –

section 2.

Figure 2 Example of Sensor Placement in the Home



Algorithms using an inference system and finite state machine computation models were developed to monitor ADL such as sleep, periods outside the home, cooking, hygiene, and general activity levels in the home (for more details see Lussier et al. [50]2020[45]). From these algorithms, it was possible to present graphical information about the daily habits of the individual to clinicians to support their decision-making process. The information was summarized on a 3-page PDF report sent directly to the clinicians.

Intervention

For the intervention phase, the POC needs to be used first-hand by practitioners from the real-life setting for which it is designed. This participatory process provides opportunities for end-users to influence and guide the design.

In early 2017, the POC was presented to clinicians and managers in team meetings in the identified testing sector. Clinicians were invited to identify older home care recipients for whom they thought ADL telemonitoring would be useful. Clinicians who wished to participate filled in a request form about their needs and the care recipient they identified. Complex cases were discussed with the research team to ensure that the needs of the clinician were within the scope of ADL telemonitoring. Recruitment procedures are detailed in Appendix 1 -section 3.

Evaluation

The general objective of the alpha cycle was to document the feasibility of using ADL telemonitoring in real-life settings, and to quickly iterate the POC. More specifically, the objectives pursued were: 1) to describe the characteristics of the participants and their demands for telemonitoring; 2) to describe the usage and impact of the POC by the home care teams; and 3) to document the facilitators and barriers to POC usage.

To achieve these objectives, a mixed embedded single-case study design was used [51][46]. Case studies are relevant when the research question requires a comprehensive description of a social phenomenon[51][46], as is the case here in studying the perspectives of different stakeholders on the feasibility of using technology. The single case was the home care division of the IHSSC CIUSSS

where the monitoring technology was integrated into one CLSC. The six subunits consisted of a care recipient ($n=6$), their clinicians ($n=8$; two were replaced during the project) from home care services and, when possible, a family caregiver ($n=2$) (see Figure 3). These subunits made it possible to shed light on the personalized trajectories of each care recipient, as well as intended and actual use of the system in relation to these trajectories. Appendix 1 – section 6 provides more details about the subunits and data analysis methods. A mix of quantitative and qualitative data was collected. Table 1 provides an overview of the data collection process in the Alpha cycle.

Figure 3 Diagram of embedded case study

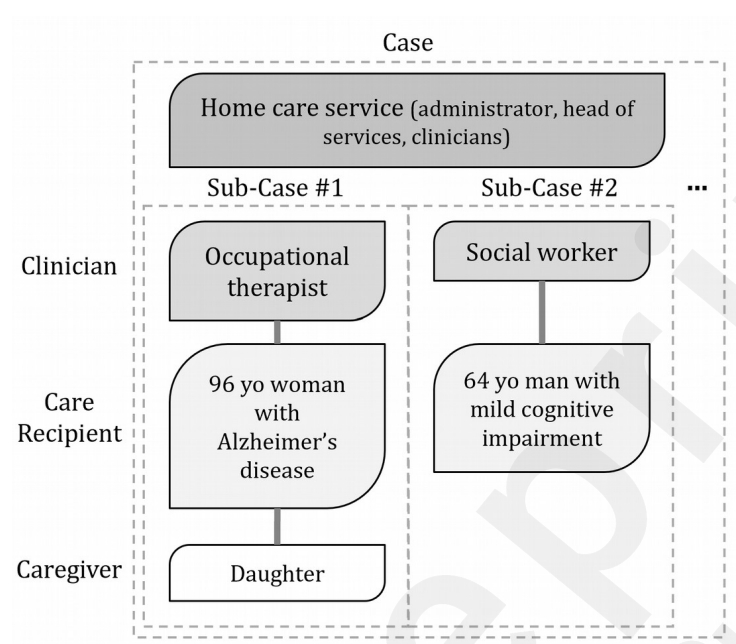


Table 1 Overview of the alpha cycle data collection, sample, measurements and variables in the evaluation stage

Data collection and sample	Measurements and variables
Telemonitoring request form filled out by clinicians and with follow-up questions on phone interviews	• Facilitators and barriers to home care of care recipients • Demands for telehealth technology
Characteristics of clinicians (n=8) and care recipient (n=6)	• For Clinicians: Profession • For care recipients only: Age, Sex, years of schooling, Mini-Mental State Evaluation (MMSE), Montréal Cognitive assessment (MOCA) Multi-client assessment tool (OEMC) Functional Autonomy Measurement System profile (Iso-Smaf), Metadata on home care service received, Cognitive evaluation (Rey Auditory Verbal Learning, Mini-GDS, and D-KEFS Trail making test, Stroop test, and Tower Test), Instrumental Activity Profile (IAP)
Initial individual interviews with care recipients (n=6) and caregivers (n=2)	• Facilitators and barriers to home care of care recipients • Anticipated leverages and obstacles to telemonitoring deployment in home care
Three follow-up focus groups with clinicians after POC installations (n=8)	• Observed facilitators and barriers to telemonitoring deployment • Use-case, impacts and general satisfaction toward deployment
Post-deployment focus groups with administrators (n=2); heads of services (n=5); clinicians (n=8)	• General facilitators and barriers to telemonitoring deployment and sustainability • Impacts and general satisfaction toward telemonitoring

Characteristics of Participants and Demands for ADL Telemonitoring

With the care recipients' consent, medical history was extracted, including cognitive screening scores, as well as needs for home care support, socio-demographic information and the quantity of home care services required. Metadata was also extracted from the medical records about each service provided by the health network for each care recipient respectively (i.e., type of act, its time and duration, etc.). Finally, to obtain a more in-depth cognitive profile of each care recipient, a cognitive evaluation was completed by a research assistant as well as an evaluation of ADL performance. For more details, see Appendix 1 – section 6.

Clinicians who identified a care recipient and wished to participate filled out a request form detailing their demands for telemonitoring, the reasons that led them to request remote monitoring for this care recipient and which ADL they would like to obtain more information about via telemonitoring. Through interviews, they were also asked about facilitators and barriers to home care for this specific care recipient. After receiving the form, a research assistant called the clinician to provide any further details or clarifications as needed.

Usage and Benefits of ADL Telemonitoring

During the follow-up focus groups, clinicians were asked how the telemonitoring was used, for which ADL, and how it influenced their decision-making process regarding the recipients' care plan. They were also asked about their satisfaction and whether it was relevant, or not, to continue telemonitoring for each care recipient and why.

Finally, during post-deployment focus groups, administrators, heads of services, and clinicians were asked about their general satisfaction toward telemonitoring as well as the benefits it had on clinical practice.

Facilitators and Barriers to ADL Telemonitoring Deployment

During the initial interviews, care recipients and caregivers were asked if they foresaw any barriers and facilitators to the deployment of the ADL telemonitoring system. Also, to document their

perceived needs, they were asked to describe ADLs that were difficult for them to perform, the current help they received and their unmet care support needs.

At follow-up focus groups, clinicians were asked about the facilitators and obstacles they encountered during the deployment.

During post-deployment focus groups, participating clinicians and managers were asked about elements that could promote or hinder deployment of the ADL telemonitoring system in their organization, as well as their thoughts regarding the sustainability of this type of system.

Finally, throughout the study, data on several additional factors to be considered were collected: occurrence of adverse events; clinician turnover; reason for care recipient's withdrawal, relocation or hospitalization; or cause of death.

Ethical Considerations

The alpha cycle was approved by the Ethics Review Board of the Centre de recherche de l'Institut universitaire de gériatrie de Montréal (CRIUGM) (CER VN 16-17-22). All participants (i.e., care recipients, clinicians, caregivers, and managers) gave their informed and written consent before taking part in the data collection process. Information that could potentially identify participants was securely stored in a locked storage unit or protected by passwords. Whenever possible, data were de-identified through codification. Participants did not receive any monetary compensation.

Results

Reflection and learning

The reflection and learning stages of ADR mirror a conventional Results section, entailing the analyses and interpretation of the data collected during the evaluation phase. The alpha cycle aimed to develop and deploy the POC in a real-life context, as well as to quickly reveal anticipated and unanticipated outcomes about technology usage and deployment. Below, we synthesize the outcomes for each of the three objectives. For more details about outcomes, see Appendix 1 – section 5.

Characteristics of Participants and Demands for ADL Telemonitoring

The system was deployed in the homes of four care recipients with severe cognitive deficits. All lived alone and half had family caregivers. Participating clinicians included three occupational therapists, three nurses, and two social workers.

During these interviews, social and health care professionals expressed the need for monitoring data to support their clinical decision-making process. More precisely, they wanted access to technology that could help assess and manage risks involved in maintaining care recipients at home. In other words, their aim was to gain a better understanding of how care recipients were functioning in their homes. This information would support their intervention plan and help determine which services should be put in place.

Usage and Benefits of ADL Telemonitoring

The evaluation stage revealed that the ADL telemonitoring system was used by clinicians to collect additional and reliable data about the home care recipient's ADL routine (for more details, see Lussier et al. [17]2020[13]). In accordance with the demands for ADL telemonitoring, the technology made it possible to gain a better understanding of how care recipients were functioning in their home, providing an objective measure that complemented other subjective clinical evaluations. More precisely, it was used to confirm or refute hypotheses before developing a comprehensive intervention plan. It was also used to facilitate discussions with the older adult and their family based on consensual information.

[17]Overall, clinicians described the monitoring technology as a useful tool to allocate home care services that corresponded to the needs of care recipients and to optimize their autonomy and safety [13].

Facilitators and Barriers of ADL Telemonitoring Deployment

Overall, the alpha cycle presented several encouraging results regarding the POC's perceived usefulness and reported satisfaction, as well as the feasibility of its [43]deployment in SAPA teams operating in the field [39]. While the prototype was successfully deployed in four care recipients' homes, several obstacles were encountered. Three main obstacles were identified: the characteristics of some participants, the burdensome evaluation protocol and the level of maturity of the POC.

First, the technology used for the prototype was suboptimal for some care recipients' profiles. More specifically, a concern was expressed that sensors would exacerbate symptoms of a paranoid personality disorder with invasive thoughts, and consequently the care recipient was not included in further testing. Also, the usefulness of the sensors with care recipients presenting important mobility challenges was questioned. For instance, these care recipients performed very few ADL by themselves and moved around their unit in a wheelchair – which decreased monitoring efficiency and accuracy.

Second, the alpha cycle protocol allowed us to better understand the population followed by the CSLC and to refine the protocol for evaluating care recipients' characteristics. In fact, our original protocol was too long, formal and confronting for many care recipients, increasing the risk of a refusal to participate in the study or withdrawal. It was thus decided that formal evaluations with care recipients would be reduced as much as possible in subsequent cycles.

Overall, feedback showed that the prototype was not ready for wider deployment: the installation took too long, data processing was too slow, output analysis was complex and time consuming, mostly done by hand, etc. Finally, despite the lack of real danger, it was decided that water sensors were to be mostly avoided in the future, as they were the only type of sensors that generated anxiety and worry in almost all care recipients, because of their concerns regarding having wires near water.

Beta Cycle

Methods

Building, Intervention, Evaluation (BIE)

Following the alpha cycle stage and the deployment of the POC, CIUSSS 1 was interested in participating in a second cycle of development with a wider deployment. Also, during the alpha cycle, two additional institutions from the Greater Montreal area (CIUSSS 2, CISSS 3) manifested their interest in using the ADL telemonitoring system and researchers from our team met with managers and clinicians from these institutions. They identified needs and challenges to home care of older adults with cognitive deficits that were very similar to those encountered by CIUSSS 1. As such, the beta cycle was conducted with CIUSSS 1, CIUSSS 2 and CISSS 3 without repeating the problem formulation stage. Furthermore, a second problem formulation stage was deemed non-relevant since the alpha cycle results did not indicate a need to refine our understanding of the context.

The general goals of the beta cycle were to further improve the ADL telemonitoring system based on experience gathered during the POC, and to deploy this newer version on a wider scale to further

document specific use cases and factors that could contribute to ensuring its long-term use in a real-world setting. Since the COVID-19 pandemic occurred as deployment for the beta cycle was just starting, many adjustments to the research protocol and monitoring system had to be made. They are summarized below and detailed in Appendix 1 -section 6.

Building

Between 2018 and 2019, a blitz of technological developments was undertaken to develop an edge computing based on a distributed architecture that offers more flexibility for integrating new technologies with high performance in data ingestion than the POC developed in the alpha cycle. Details of the system optimization can be found in Appendix 1 – section 7.

Organized in software modules, the system centralizes data encryption, storage, computation, communication and system robustness on a single low-power, low-cost computing device. This framework, called the iNnovative Easy Assistance System-Hub (NEARS-Hub), integrates non-intrusive sensors in the smart home[52][47].

Several features were added to build on the alpha cycle learning and address limitations. First, the deployment of sensors was optimized, which not only simplified installation, but also minimized the technician's presence in the patient's home. The latter was a particular source of concern for both clinicians and care recipients.

Second, to facilitate rapid data collection, the Vera Z-wave home controller was replaced with a Raspberry Pi 3 linked with a USB Z-wave controller, offering several options for local data preprocessing and a number of other improvements, for example, automation of collection, maintenance, and data processing, local data storage, automation of local backups to compensate for service interruptions, etc.

Third, two additional types of sensors were integrated into the ecosystem: a heavy-appliance smart electric switch to monitor oven usage and pressure mattress sensors that could be added to the bed or couch.

Fourth, a major achievement was compliance with the safety and confidentiality standards required by the Quebec Ministry of Health.

Fifth, a web-based user interface supporting advanced data visualization and comparison tools, called NEARS-SAPA, was designed for clinicians, enabling them to monitor: 1) five significant ADL (i.e., sleep, eating, mobility, activity, and hygiene); 2) relevant object usage (e.g., fridge, television, coffee maker); and 3) room occupancy. As a result, the platform provided a broad overview of the ADL performed by each care recipient, as well as some specific information regarding each ADL (for instance, the care recipient's sleeping schedule). To compensate for both the inability of research staff to train clinicians because of the pandemic, and clinicians' increased workload, the research team simplified reporting, sending a data summary electronically in Portable Document Format (PDF), highlighting the trends and changes in ADL for each care recipient every two months.

Finally, to reduce in-person home visits related to fixing technical problems, a modular and component-based information technology infrastructure was built into NEARS-HUB to solve as many maintenance issues as possible remotely.

Intervention

Strategies based on the alpha cycle were put in place to improve the deployment (see Appendix 1 –

section 8 for details). With the involvement of managers from each health institution, it was decided that the project and its opportunities would be presented during regularly scheduled meetings of each targeted profession. Coordinators from different professional teams were asked to promote the project to their colleagues. While it was not considered as an exclusion criterion, clinicians were alerted to poor acceptance and possible adverse outcomes of ADL telemonitoring in individuals with paranoid disorders and extensive mobility challenges.

Evaluation

For the beta cycle, the objectives were the following : 1) describe the characteristics of the participants and their demands for telemonitoring; 2) describe the usage and benefits of the ADL telemonitoring system on a larger scale; 3) document facilitators and barriers to its deployment; 4) evaluate the usability and acceptance of the system; and 5) estimate the costs related to system deployment and usage. To respect COVID sanitary guidelines, interviews and evaluations were all performed over the phone.

Table 2 gives an overview of the data collection process used during this cycle. Details can also be found in Appendix 1 – section 9.

Table 2 Overview of the beta cycle data collection, sample, measurements and variables in the evaluation stage

Data collection and sample	Measurements and variables
Telemonitoring request form filled out by clinicians, with follow-up questions by phone interview	- Facilitators and barriers to home care of care recipients - Demands for telehealth technology
Characteristics of clinicians (n=31) care recipient (n=31), caregivers (n=9)	- For all: Demographics - For care recipients only: Mini-Mental State Evaluation (MMSE), Montréal Cognitive assessment (MOCA) Multi-client assessment tool (OEMC) Functional Autonomy Measurement System profile (Iso-Smaf)
Pre-deployment - Individual interviews with clinicians (n=31), care recipient (n=8) and caregivers (n=9)	- Facilitators and barriers to home care of care recipient - Anticipated leverages and obstacles to telemonitoring deployment in home care - Demands for telehealth technology
During deployment - Follow-up individual interviews with clinicians (n=31) every four months	- Observed facilitators and barriers to telemonitoring deployment - Use-case, impacts and general satisfaction with telemonitoring
Questionnaires for clinicians (n=23)	10 in-house questions on usage 7 questions from the System Usability Scale (SUS) on usability 11 questions from the Technology Acceptance Model - 2 (TAM-2) on acceptance
Questionnaires for care recipients (n=23)	3 in-house questions on telemonitoring perceived usefulness 8 in-house questions on telemonitoring acceptance
Post-deployment - Focus groups with clinicians (n=8)	General facilitators and barriers to telemonitoring deployment and sustainability
Post-deployment - Individual interviews with administrators (n=2)	Impacts of and general satisfaction with telemonitoring
Estimate of direct, indirect, and intangible costs related to telemonitoring	- Material costs - Time invested - Adverse outcomes reported

Characteristics of Participants and Demands for ADL Telemonitoring

For subunit characteristics, we used the same measurements as for the alpha cycle, but dropped the cognitive and functional evaluations due to sanitary constraints and adverse reactions reported by clinicians and caregivers from the alpha cycle. For clinicians, age, sex, profession, affiliation, and number of years of experience in home care services were collected (self-reported). As in the alpha

cycle, clinicians who identified a care recipient and wished to participate filled out a request form detailing their demands for ADL telemonitoring. An initial individual interview with the clinician was added before NEARS-SAPA reports were sent to them. This interview was specifically aimed at identifying demands, facilitators and barriers to home care for this specific care recipient.

Usage and Impact of ADL Telemonitoring

Qualitative data were similar to that collected in the alpha cycle (see Table 2), with slight modifications in terms of time points and type of data collection: 1) follow-up focus group interviews with clinicians were replaced by individual interviews held every four months with clinicians following the installation of the sensors; 2) follow-up focus group interviews with administrators and managers were replaced by individual interviews at the end of the cycle.

Also, after the first follow-up interview, 10 in-house questions specifically related to the ADL telemonitoring system and reported usages were sent to clinicians in the form of a web survey. Finally, three in-house questions were administered orally to care recipients about their perceptions of the usefulness of the telemonitoring system.

Facilitators and Barriers to ADL Telemonitoring Deployment

Qualitative data was collected following procedures similar to those in the alpha cycle (see Table 2), with the same slight modifications as mentioned above in terms of time points and type of data collection.

Usability and Acceptance of ADL Telemonitoring

Usability is defined as the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular technological environments [53][48]. Several measures were added to evaluate the usability of the system. During the initial interview, clinicians were asked if they foresaw any facilitators and obstacles to their intended usage of the ADL telemonitoring system. During follow-up interviews, they were asked if there were any barriers and facilitators to their actual usage of the telemonitoring system. A web survey comprising seven questions from the System Usability Scale (SUS) [54] was also sent to clinicians. The SUS is a reliable tool for measuring such usability and the questions were oriented around the ADL telemonitoring system and reports. The survey also comprised an 11-question form built from the “perceived usefulness” and “ease of use” sections of the Technology Acceptance Model - 2 (TAM-2) questionnaire [55][49]. The TAM-2 is an information systems theory that models how users come to accept and use a technology.

To evaluate care recipients’ and caregivers’ level of acceptance of the presence of the sensors in their home, they were asked to respond to an oral questionnaire composed of 8 questions developed by the research team.

Cost Estimation of ADL Telemonitoring

We collected metadata on each service provided to care recipients by the CIUSSS/CISSS and recorded in ICLSC. ICLSC is a provincial ministry database containing personal information and providing data on service requests, users and interventions concerning services delivered. The database is used to describe front-line services to ensure the quality and efficiency of health and social services. For this study, we examined the monthly count of services received by the care recipients within the timeframe of 6 months preceding and 6 months following the clinician access to ADL telemonitoring.

Throughout this project, we aim to document the cost of implementing the ADL telemonitoring in

the public healthcare system by totaling direct, indirect, and intangible costs [56, 57][50, 51]. To do so, we documented the material costs (e.g., number of devices used, lost material, server maintenance cost, software, licenses, material for fixtures, repairs and maintenance, Internet services, database and server maintenance, etc.). We also estimated the time invested by technicians and clinicians over the study period (time for recruitment, needs analyses, installation, training, technical support, etc.). This estimate was validated by the technicians and clinicians during group interviews in the post-deployment phase. The time invested was transferred to cost using the common hourly rates for technicians and clinicians. Time dedicated exclusively to research purposes (e.g., interviews about the usability of the system) was not included in the deployment costs.

Ethical Considerations

The beta cycle was approved by the CRIUGM Ethics Review Board, mandated to be the evaluating committee in a multi-center procedure (CER VN 17-18-10). The same protocols and considerations as in the alpha cycle were followed.

Results

Reflection and Learning

Data collection ended in late-2022. In total, NEARS-SAPA was installed in 31 care recipients' homes and 34 clinicians were involved in the beta cycle. Data analyses for the beta cycle are nearing completion, and results specific to each sub-objective will be shared in the future.

Discussion

The aging population and increasing demand for ADL support faced by social and healthcare services in many countries call for the deployment of innovative solutions to better meet the needs of older adults with cognitive deficits. In close collaboration with three public healthcare institutions in the province of Quebec, we conducted a study designed to arrive at an in-depth understanding of the potential of ADL telemonitoring to support older adults with cognitive decline in the context of a public healthcare system. More specifically, the objectives of the project were to: (1) Co-develop an ADL telemonitoring system that addresses the needs of all key stakeholders involved in home care services for older adults with cognitive deficits, including the older adults and their caregivers; (2) Deploy ADL telemonitoring in the Quebec public healthcare system and identify the specific use cases; (3) Identify factors that could contribute to ensuring its long-term use in a real-world setting (i.e., participants' characteristics, demands and usage of the telemonitoring, facilitators and obstacles to its deployment, usability and acceptance, and estimated cost of the system). To achieve these objectives, we opted for an innovative research approach with an ADR and engaged with all stakeholders involved in home care services through two iterative cycles of system co-development.

[35]The publication of our protocol was part of the completion of the Formalization of learning stage, the last ADR stage comprising identification of artifacts, generalization of learning, and dissemination. These three components will be addressed in this discussion section.

Identification of Artifacts

In this paper, we reported the ADR protocol of the SAPA project and its related artifacts. As a form of ADR results, an artifact encompasses tangible or intangible elements, including objects, documents, processes, or outcomes, shaped by the ADR processes. These artifacts serve as tangible proof of the actions taken and the resulting benefits within the research context. The SAPA project has given rise to information-technology artifacts, such as NEARS-SAPA (a web-based user interface supporting advanced data visualization and comparison tools) and NEARS-Hub (an IoT infrastructure model) [47]. Additionally, scientific and clinical artifacts, such as the outcomes of the

alpha cycle, have been published in the form of case study papers [13, 45]. From data gathered within the beta cycle, our objective is to generate more artifacts, such as presenting comprehensive documentation and analyses of use cases, along with factors supporting or limiting the deployment of the ADL telemonitoring system. This endeavor aims to contribute valuable scientific insights into the clinicians' decision-making processes and deployment strategies that will further support the adoption and integration of ADL telemonitoring in real-life home care contexts.

Generalization of Learning

This protocol paper also provides a thorough presentation of the entire project and its intricate phases. It illustrates how ADR principles could apply to the field of ADL telemonitoring, enabling stakeholders to be actively involved in developing technology that is useful, acceptable, and deployable in real-life environments. To our knowledge, a comprehensive ADR protocol, spanning two cycles of development, had not been published so far in the field of smart environments and ADL telemonitoring. This is surprising since ADR offers a promising framework for developing practical technological solutions to complex problems, such as in healthcare services [34, 36]. In this context, we present the detailed ADR protocol of this project as an outcome/artifact, enabling the replication of similar projects in the future and the generalization of our results.

Furthermore, the SAPA project and ADR protocol are innovative as they include and report steps involved when ADL telemonitoring is deployed in real-life. A recent umbrella review conducted by our team [31] revealed that few real-world deployment studies have been undertaken in the field of smart environments thus far. As an emerging area of research, the published studies have primarily focused on the development and conceptualization of technological components, with only a limited number involving small-scale testing in a laboratory context. Consequently, there is limited published data on the deployment strategies required to integrate smart environments into the healthcare system or community, [31] and our project was designed to fill this gap.

To our knowledge, we are the first to have co-developed and deployed a system in iterative cycles of collaboration with all stakeholders involved in home care support in the context of a public social and healthcare system. Co-construction and collaboration are at the heart of ADR principles. Other studies have reported the deployment of similar solutions, but the development and/or deployment were not carried out using a co-construction approach in partnership with a healthcare system and did not consider how stakeholders wish to integrate the telemonitoring information into their practice[18, 52-54]. It has been shown that the co-development of technological solutions with all stakeholders and users is an important factor to ensure that the deployment of sustainable technological solutions proceeds smoothly and leads to their long-term adoption[61][59] [55]. Our protocol, centered on codesign, use cases, and deployment factors, is parallel to another recently published protocol reporting a clinical trial to document the effectiveness of an ADL telemonitoring platform via a quasi-experimental study [56]. In that study, more than 73 older adults will receive an active and assisted living-based multiservice assistance platform, called HomeAssist. The platform includes ADL telemonitoring but also many applications designed for the older adults themselves to help them engage in their daily and social activities. While the HomeAssist project has not yet been deployed in the home care services context at the time of publication, this type of project is key to advancing the field of ADL telemonitoring, for which very few rigorous experimental data exist thus far [35][31]. As for ADR procedures, the present study illustrates how to realize various cycles of co-construction and co-deployment of a technology in close collaboration with stakeholders.

While the SAPA project is innovative in terms of its vision and methodology, it operates on a

relatively small scale. Therefore, it will be important to conduct larger-scale studies in the future. As a next step, we intend to conduct an evaluative study to report the benefits of ADL telemonitoring. These benefits could include, for instance, effectiveness in terms of clinician productivity and work, older adults' functional independence, use of other health services and change of living environment, as well as benefits for the institutions in terms of cost effectiveness [62][56]. To engage in these types of larger-scale evaluations, we recommend that research teams in the field of ADL telemonitoring rely on recognized models or frameworks of technology implementation and adoption that are well established in digital health fields. For example, the Nonadoption, Abandonment, Scale-up, Spread, and Sustainability (NASSS) framework of Greenhalgh et al. [61] enables anticipation of the challenges that may arise during the implementation of an eHealth system in a particular environment[62]. As another example, the Clinical adoption framework [56] takes into account micro, meso and macro dimensions that influence the long-term adoption and sustainability of technological solutions. The use of such frameworks will ensure rigorous development of ADL telemonitoring supported by sophisticated data.

Dissemination

Finally, in terms of dissemination, initial findings from the beta cycle were shared with the participating program managers, heads of services, and clinicians from the CIUSSS/CIUSSS. Ultimately, the comprehensive results and assessments will be shared with the scientific community, providers of home care services for older adults, as well as managers and policymakers. There has been discussion about progressing toward a third cycle of development. The primary objective for such a cycle would be to make NEARS-SAPA fully independent of the research team. Currently, the technology relies on support, supervision, and knowledge transfer from the research team for optimal functionality, posing a significant barrier to broader implementation, including integration into clinical processes, and cost-effectiveness.

Conclusion

This paper reports the protocol of the SAPA project that used an ADR framework to co-develop and deploy an ADL telemonitoring system in the Canadian public social and healthcare system. Through two ADR iterative cycles, the SAPA project made it possible to consider all stakeholders' needs, expectations and perceptions in the final telemonitoring strategies proposed as well as the imperatives related to the deployment of such solutions in real-test environments. Future studies could follow this protocol and further develop some methodological aspects.

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Abbreviations

Action design research (ADR)

Building, intervention, evaluation (BIE)

Centre de recherche de l'institut universitaire de gériatrie de Montréal (CRIUGM)

Centres locaux de services communautaires (CLSC)

Functional autonomy measurement system profile / *Système de mesure de l'autonomie fonctionnelle* (SMAF)

Global positioning system (GPS)

Innovative easy assistance system (NEARS)

Instrumental Activity Profile (IAP)

Integrated health and social services centre / *Centres intégrés de santé et de services sociaux* (CISSS)

Integrated university health and social services centre / *Centre intégré universitaire de santé et de services sociaux* (CIUSSS)

Mini-Mental State Evaluation (MMSE)

Montréal Cognitive assessment (MOCA)

Multi-client assessment tool / *Outil d'Évaluation Multi-Clientèle* (OEMC)

Passive infrared (PIR)

Portable Document Format (PDF)

Proof of concept (POC)

Radio-frequency identification (RFID)

Support program for the autonomy of seniors / *Soutien à l'autonomie des personnes âgées* (SAPA)

System Usability Scale (SUS)

Technology Acceptance Model - 2 (TAM-2)

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Appendix 1 NEARS-SAPA Project

Supplementary Methodological Details

Alpha cycle	
1. Problem Formulation	The perspectives of the following stakeholders were explored: • administrators, who are responsible for managing budgets and resources within the SAPA program (i.e., the director, the associate director, the department head and the program managers of home care services) (n=2); • head of services (n=5); • clinicians (i.e., social and healthcare clinicians such as social workers, nurses, occupational and physical therapists) who conduct the evaluation, planning and delivery of services for home care (n=8); • care recipients (n=5); • caregivers (n=3). The interviews were led by an experienced facilitator in qualitative research, and an observer took notes during focus groups to summarize the main ideas for approval by the group at the end of the sessions. All interviews and focus groups were audiotaped and transcribed. The verbatims were analyzed following a thematic content analysis method as described by Miles, Huberman and Saldana's [60].
2. Building	Sensors: Four types of wireless sensors were used: passive infrared (PIR) sensors, magnetic contact sensors, smart electric switches, and water sensors. • PIR sensors detect motion by receiving infrared radiation. They were used primarily to determine room occupation: after a PIR sensor was triggered in one room, the occupant was considered to occupy it for as long as the PIR sensor in another room was not triggered. PIR sensors were installed in the bedroom, kitchen, dining room, living room, entrance, and bathroom. One or two sensors were installed in most rooms depending on the size and layout of the room; • Magnetic contact sensors were used on the various cupboards or doors. A contact sensor was always installed on the front door and on the main drawer (or wardrobe door) used for clothing (e.g., underwear drawer). In the kitchen, the location and number of sensors varied depending on the layout and the occupant's routine. The refrigerator, freezer, utensil drawer, kitchen cabinet (for pans, cups, plates), and one food storage cabinet, were equipped with sensors if possible and relevant, according to the occupant's self-reported routine. • Smart electric switches were installed on the television and the microwave. Toaster, coffeemaker, and bedside lamp use could also be monitored if relevant, according to the

	occupant's self-reported routine. Water sensors were used in the bathroom sink, as well as the shower, to further help recognize activities related to hygiene.
3. Intervention	Recruitment procedures: - Inclusion criteria for care recipients were : 1) living with a loss of functional autonomy requiring home care services; 2) being 65 years of age and older or presenting a geriatric profile (i.e., multiple pathologies that require the intervention of a multidisciplinary team, functional decline with a risk of deterioration of health status or with a risk of hospitalization[61]). - If the case met the inclusion criteria, the clinician contacted the care recipient to briefly present the study and receive verbal consent to schedule a meeting at their home with a member of the research team. - When applicable, the care recipient's caregiver was invited to this meeting and could participate in the research project as well. During that meeting, more information about the research project and the technology was given, and informed written consents were obtained.
4. Evaluation	Sub-units: - It should be noted that clinicians could change over the course of the project, due to leave, employee turnover, and organizational reallocation of resources. - Clinicians could recruit more than one care recipient and therefore participate in more than one subunit. - Many care recipients did not have a caregiver, or their caregivers were not available or interested in participating. Therefore, some subunits consisted only of a clinician and a care recipient. Data analysis: - Qualitative data from recordings of the focus groups and the individual interviews were transcribed by a person specialized in this type of work and checked by a member of the research team. - Data analysis was performed using Miles, Huberman and Saldana's method[60]. More precisely, three processes were used: memos, data codification, and matrix building. First, descriptive codes were created, which labelled units of text (words, sentences, paragraphs) that encompassed a distinct meaning. The coding grid emerged from the data. A brief definition of each code was developed as the coding process progressed. A list of codes, each supported by excerpts from interviews, was created. Codification was performed by research assistants and validated by two researchers (MC, NB). Second,

	matrices were used to compare data according to stakeholders. Matrix-building was done jointly by a researcher specialized in qualitative research (MC) and research assistants. • For quantitative data, descriptive analyses of average and standard deviation were used.
	Characteristics of care recipients: With the care recipients' consent, access to medical records was granted from January 2016 until the end of the participation. These data were extracted: • Medical history; • Scores on the Mini-Mental State Evaluation (MMSE), Montréal Cognitive Assessment (MOCA). MMSE and MOCA are cognitive screening tests often used by health professionals in the detection of mild cognitive impairment and Alzheimer's disease [62, 63]. • Score on the Multi-client assessment tool (Outil d'Évaluation Multi-Clientèle: OEMC). The OEMC is an instrument used by all home care clinicians in the province of Québec, that facilitates and supports their own work, or multidisciplinary teams, in translating requests into needs, translating needs into services, and allocating available resources according to the needs of the care recipient [64]. It is composed of six forms, including a summary form that contains the intervention plan of the various actors involved with the care recipient. The OEMC also provides several demographic characteristics of the care recipient (i.e., age, gender, sex, education, medical diagnoses, living situation) as well as the Functional Autonomy Measurement System profile (<i>Système de mesure de l'autonomie fonctionnelle</i> : SMAF[65]). • The SMAF is a four-level rating scale used to quantify a subject's functional autonomy based on 29 functions among five types of activities, namely 1) ADL; 2) mobility; 3) communication; 4) mental functions; and 5) instrumental ADL. Following the completion of the SMAF by a clinician from home care services, individuals are classified according to the intensity and the type of services required to maintain their autonomy based on the information provided in the ISO-SMAF profiles. The ISO-SMAF classification consists of 14 homogeneous disability profiles characterized by a gradual progression in the severity of disabilities. • Metadata was also extracted from the medical records about each service provided by the health network for each care recipient respectively (from January 2016 until the end of their participation). This metadata detailed several variables for each service performed (i.e., type of act, reason for this act, its time and duration, the type of professional performing it, and its location).

	Cognitive evaluation (Rey Auditory Verbal Learning[66], Mini-Geriatric Depression Scale[67], and D-KEFS Trail making test, Stroop test, and Tower Test [68]) and the Instrumental Activity Profile (IAP)[69] were completed by a research assistant with the care recipient.
5. Reflection and learning	Characteristics of subunits The POC was deployed within one CLSC of CIUSSS 1 from 2017 to 2018. Care recipient participants: • Six potential home care recipients were identified, and the system was deployed in four care recipients' homes. ◦ One installation was discontinued for a care recipient with paranoid personality disorder, as it was deemed potentially too stressful. • Care recipients were aged 73yo $\pm$20 with an average of 11$\pm$7 years of schooling. All lived alone in a rented apartment. Two had family caregivers, two had neighbor caregivers and one had no caregiver. Their average MOCA score was 17$\pm$5. • Two participants had a diagnosis of multiple sclerosis. They were significantly younger (50yo$\pm$1) and scored predominant motor impairment on the SMAF (4 and 9). • Three other participants had various diagnoses of cognitive impairment (vascular cognitive impairment, subcortical dementia, and mild cognitive impairment). They were significantly older (90yo$\pm$2). • On the SMAF scale, one scored impairment limited to ADL (1) and the other two scored predominant motor impairment (5, 7). One participant had no diagnosed cognitive impairment despite having a low score on the MOCA scale (20). Her main medical condition was anxiety and risk of fall, and she scored impairment limited to ADL (1) on the SMAF scale. Participating clinicians included three occupational therapists, three nurses, and two social workers.
	Documenting the implementation Obstacles: 1) The technology used for the prototype was suboptimal for some care recipients' profiles. a. In one case, a care recipient with paranoid personality disorder and invasive thoughts about being robbed by a neighbor was referred to the project. At first, the clinician thought that the sensors could reassure him by showing that there was no intrusion in the home. However, following

discussions with both the care recipient, their caregiver, and their clinician, it was decided that ADL telemonitoring should not be installed because the presence of the sensors could exacerbate his paranoid thoughts and feelings of being spied on.

- b. Care recipients with important mobility challenges also appeared to benefit less from the ADL telemonitoring. Two participants with multiple lateral sclerosis were referred to the project because of their cognitive deficits. They had several support services (e.g., assistance with moving in and out of the bed, toilet, or bath). This limited the usefulness of the sensors as only a few actions related to ADL were performed without the presence of home care services. Both participants moved around their apartment in a wheelchair, therefore decreasing the monitoring efficiency and accuracy. Moreover, most objects they interacted with daily (e.g., clothes, food, dishware) were at their disposal on countertops instead of being stored away in drawers and cupboards, rendering contact sensors mostly useless. Because of mobility issues, the activities commonly associated with specific rooms were carried out in different locations. For instance, one participant slept, ate, and watched television on his adapted chair in the living room. Subsequently, it was decided to communicate to clinicians during the care recipient selection process that the technology was of limited usefulness for care recipients experiencing paranoid personality disorder or important mobility challenges.

2) Second, the alpha cycle protocol allowed us to better understand the population followed by the CSLC and to **refine the protocol for evaluating care recipients' characteristics.**

- a. The original protocol comprised many formal evaluations, including cognitive and ADL function testing to characterize the population. The clinicians mentioned that most care recipients who would benefit from ADL telemonitoring often do not respond well to formal evaluations. They added that several candidates would 1) be reluctant to be evaluated, 2) be unreliable in their answers or try to conceal their deficits, and 3) react with opposition and distrust if confronted with their personal challenges. This is especially true for those who fear being moved out of their home. Therefore, such a formal and confronting evaluation could lead to 1) refusal to participate or withdrawal from the study, 2)

	damage to the relationship between the care recipient and the clinician who suggested the project, and 3) increased intervention fatigue due to interaction with research staff (leading to more refusal of services offered by SAPA). As a result, clinicians might have more concerns and be reluctant to refer their care recipients to the telemonitoring program. For subsequent cycles, it was thus decided that formal evaluations with care recipients would be reduced as much as possible. 3) The prototype was not ready for larger deployment. - Installation required three hours of work at the care recipients' home and several subsequent visits to adjust the sensors. - Data gathering and processing were too slow to support more than five apartments simultaneously. - Statistical output was limited, hard to interpret, and time-consuming to produce. - Several aspects of data processing lacked automation and had to be launched manually. - The prototype did not meet the web-security criteria for larger deployment in Québec health institutions.
Beta cycle	
6. Impacts of COVID-19	This cycle took place between late-2018 and late-2022. Throughout 2019, a significant amount of time was devoted to technological developments. Recruitment of new participants started in late 2019. Therefore, the COVID-19 pandemic occurred as deployment for the beta cycle was just starting. The following limitations led to several modifications of the research protocol and monitoring system: - Recruitment and deployment had to be delayed significantly in response to the emergency measures. - New challenges needed to be addressed to continue recruitment. - First, several hygiene protocols had to be followed and contact with participants had to be reduced to the strict minimum. - Second, clinicians were highly solicited to respond to health emergencies and had less availability for research – limiting our access to recruitment. - Third, to prevent COVID-19 outbreaks, only authorized personnel could enter health care institutions. This meant that the research assistant could no longer install the telemonitoring platform on clinicians' computers and train them to use the system.
7. Building	System optimization: The deployment of sensors was optimized. Each system was prepared in advance in the research lab and sensors

were identified, paired, and customized to match the home of the recipient. As a result, a shorter presence of the technician was required in the patient home for deployment (between 1½ and 2 hours, compared to 3 hours during the alpha cycle).

- 2) To facilitate **rapid data collection**, the Vera Z-wave home controller was replaced with a Raspberry Pi 3 linked to a USB Z-wave controller, offering several options for local data preprocessing as well as a number of other improvements. To modulate the services, the software components use a microservices architecture distributed around an event management platform in the form of streams.
- 3) Knowing that in an active and assisted living system, the collection of ambient information is central to activity recognition, software layers have been built to **automate the collection, maintenance, and processing of data**. This automation significantly speeds up the process and reduces the possibility of errors.
- 4) In case of Internet failure, data for sensors was **stored locally** until connectivity issues could be restored.
- 5) We improved the **robustness and reliability** of the information processing tools by distributing the processing over several calculation units and by automating local backups to compensate for service interruptions.
- 6) Achieving **compliance with the security and confidentiality standards** of the Québec Ministry of Health was a major achievement. We did so by providing a three-step technology solution. In other words, three complementary scales were developed for system security: 1) at the level of data collection, information was encrypted directly on the module installed in the care recipients' home. On the different communication channels, attributes were encrypted in order to render the means of communication unreadable; 2) when transmitting data to our servers, we used the SSL communication protocol, for end-to-end encryption; and 3) a self-generated and self-signed certificate was set up to allow the clinicians to connect to the data visualization platform in a secure way, yet were restricted to data on their own care recipients.
- 7) Changes had to be made in response to **challenges raised by the pandemic**. Considering that health institutions could only be accessed by their own personnel, the research team could not gain access the clinicians' office computers to

	install secure access to the NEARS-SAPA online and to demonstrate how to use the platform. Furthermore, as mentioned above, clinicians' workload increased significantly. As such, clinicians and managers asked us to simplify the monitoring reports by describing how to read each infographic and highlighting key elements that could help in clinical decision-making. Given these obstacles, it was decided that the research team would consult the NEARS-SAPA platform and send clinicians monitoring reports in Portable Document Format (PDF) every two months, highlighting the trends and changes in ADL for each care recipient. This was deemed the most efficient way to share the monitoring data with clinicians in the context of the pandemic.
8. Intervention	Based on prior experience, implementation strategies were put in place to improve the implementation process for the beta cycle: 1) With the involvement of managers from each health institution, it was decided that the project would be presented during regular scheduled meetings of each targeted profession (i.e., occupational therapists, physiotherapists, social workers, nurses, nutritionists, and respiratory therapists). During these presentations, clinicians were presented with: 1) personas and case applications for NEARS-SAPA; 2) a summary of the involvement required from them and their care recipient if they chose to participate, and; 3) the procedure for participating in the study. 2) Coordinators from different professional teams were asked to promote the project to their colleagues. 3) While it was not considered as an exclusion criterion, clinicians were warned about poor acceptance and possible adverse outcomes of ADL telemonitoring in individuals with paranoid disorders, especially if related to the fear of being observed and spied on. 4) Clinicians were also informed that ADL telemonitoring would be less accurate with individuals with low mobility, especially if they used a wheelchair and needed human assistance for transfers, dressing, washing themselves, and going to the bathroom.
9. Evaluation	Data analysis: For qualitative data, the same analysis described in the alpha cycle was used. For quantitative data, descriptive analyses of average and standard deviation were used as well as regression, one-way analysis of variance and chi square depending on whether the variables were parametric or not.



Supplementary Files

Multimedia Appendixes

NEARS-SAPA Project Supplementary Methodological Details.

URL: <http://asset.jmir.pub/assets/db91dbd6519e66253e81c77f76dfc4aa.docx>