Integrating an Ambient Assisted Living monitoring system into clinical decision-making in home care: An embedded case study

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M. Lussier, M. Couture, M. Moreau, C. Laliberté, S. Giroux, H. Pigot, S. Gaboury, K. Bouchard, P. Belchior, C. Bottari, G. Paré, C. Consel, N. Bier. Integrating an Ambient Assisted Living monitoring system into clinical decision-making in home care: An embedded case study. Gerontechnology 2020;19(1):77-92; https://doi.org/10.4017/gt.2020.19.1.008.00 **Background** In Quebec, home care administrators are increasingly open to using Ambient Assisted Living (AAL) technologies as part of services to better support care recipient with a major loss of autonomy. However, little information is available about how these technologies are integrated into clinical practice. **Research aim** The present revelatory embedded single-case study aimed to understand how AAL monitoring technologies were integrated in the clinical decision-making process of social and health care professionals to maintain older adults at risk of self-neglect at home (n = 3). **Methods** Multiple data collection methods were used for triangulation purposes: semi-structured individual and group interviews, encrypted data from monitoring technologies, medical records, and cognitive and functional evaluations. Data was analyzed using the approach of Miles, Huberman and Saldana (2004). **Results** Results show that AAL monitoring technologies were used by social and health care professionals as a means to collect additional and reliable

data about home care recipients' life habits, such as daily patterns related to eating, sleeping, personal care, inactivity and going outside. Professionals wanted to confirm or refute their own hypotheses before developing a comprehensive intervention plan. This information was then used to attribute home care services that correspond to the needs of the care recipient to optimise autonomy and security. **Conclusion** Results showed that AAL monitoring technologies provide the professionals with information that would otherwise be inaccessible and are conceptualized as a means of using social and health care resources wisely in a context where resources are scarce.

Keywords: Smart home, Ambient Assisted Living, self-neglect, aging, activities of daily living, health monitoring, social and health care

Introduction

Most older adults prefer living in their own homes, independently, for as long as they are able to (Santé Canada, 2012). In addition, institutional care is costlier for social and health care systems than aging at home (World Health Organization, 2007). However, as the proportion of older persons grows worldwide, social and health care systems are faced with unprecedented challenges in allocating resources. Several conditions compromise the autonomy of older adults and exert greater pressure on home care services. One such condition is multiple chronic diseases: currently, 90% of Americans aged 75 and older have at least one chronic medical condition, and 20% have five or more chronic illnesses (AARP, 2009). Those with multiple chronic diseases tend to be high users of health care services and account for 75% of total health care costs in the U.S. (Milani & Lavie, 2015) and 60% in Canada(Anderson, 2010). Another condition is cognitive impairment as patients with cognitive deficits have more direct medical expenses and use more health services (Ton et al., 2017). However, they are less likely to use outpatient services or to visit a doctor than cognitively normal patients (Ton, DeLeire, May, Hou, Tebeka, Chen, & Chodosh, 2017). Recent studies found that older adults living at home with cognitive impairment experience better quality of life, have better cognitive function, are less depressed and more socially active than those living in a nursing home, and this even after stratifying for severity of dementia (Mattimore et al., 1997; Nikmat, Al-Mashoor, & Hashim, 2015; Olsen et al., 2016). This suggests that staying home for as long as possible has health benefits for older adults with cognitive impairment, but appropriate home care services must be provided. Finally, self-neglect in older adults also exert great pressure on home care services. Self-neglect is a multifaceted behavioral entity involving the inability or refusal to attend adequately to one's own basic needs, such as health, hygiene, nutrition, or social needs (Lachs, Williams, O'Brien, Hurst, & Horwitz, 1997). Self-neglect is associated with less adequate social resources and more self-reported depression in older adults (Burnett et al., 2007; Hansen, Flores, Coverdale, & Burnett, 2016). Recent large population studies in the United States (Dong, Simon, Mosqueda, & Evans, 2012) indicate that self-neglect has a prevalence of about 9%, and may even reach 15% in older people with low socio-economic status, cognitive deficits or physical disabilities (Dong & Simon, 2013). In Quebec, where the present study was conducted, it is estimated that this population represents about 50% of the clientele receiving home care public services in certain areas of Montreal (Gouvernement du Québec, 1992).

In the face of these challenges, Ambient Assisted Living (AAL) represents one promising ways of addressing the complexity of home care in an older adult population and helping them maintain a sufficient level of autonomy to stay home independently and safely as long as possible (Liu, Stroulia, Nikolaidis, Miguel-Cruz, & Rios Rincon, 2016; Reeder et al., 2013). AAL is a multidisciplinary field that uses information and communication technologies in personal health care and telehealth systems within the home to aid health and well-being in older age (Blackman et al., 2016; Memon, Wagner, Pedersen, Beevi, & Hansen, 2014). Most technological solutions available today focus mainly on monitoring care recipients (Calvaresi et al., 2017). In AAL, monitoring can be conducted passively through the use of technologies such as sensors (i.e., motion sensors, contact sensors) and actuators (i.e., switch, heaters, lamps), connected through a smart hub, and set up in a residential setting (Reeder, Meyer, Lazar, Chaudhuri, Thompson, & Demiris, 2013). According to Kang et al. (2010), there are two main approaches to AAL monitoring: 1) providing alerts of adverse events, and 2) monitoring risk factors to improve management. The first approach aims to detect abnormal or dangerous events (such as falls, cardiac arrest or bradycardia) and to provide alerts, if necessary, to the appropriate resources. The second approach aims to monitor risk factors and provide information to support hypothesis regarding care recipients' situation. In this approach, AAL provides rich and reliable data to the clinician so as to improve care recipient management.

There have been several breakthroughs in AAL monitoring over the years, especially for continu-

ous physiological data monitoring (detection or prevention). For instance, heart failure, cardiac arrhythmia, or sudden death can be predicted using heart rate variability over long periods of time (Huikuri et al., 1998; Mäkikallio et al., 2001; Meyerfeldt et al., 2002). Sleep deficit and sleep apnea can be detected using overnight electrocardiography (Kesek, Franklin, Sahlin, & Lindberg, 2009; Thomas, Mietus, Peng, & Goldberger, 2005). Pharmacological interventions in persons with Parkinson's Disease can be guided by sensors that assess motor fluctuations (Patel et al., 2007). Urinary tract infections in older adults have been detected earlier by monitoring the frequency of bathroom visits (Rantz et al., 2011). Studies have also shown the possibility to detect mild cognitive impairments or Alzheimer's disease based on simple markers such as walking speed (Akl, Taati, & Mihailidis, 2015; Kaye et al., 2012; Kaye et al., 2011) or time spent completing activities of daily living (Dawadi, Cook, Schmitter-Edgecombe, & Parsey, 2013). In this respect, a recent review of the literature reported that cognitive deficits could also be detected by smart home monitoring of general activity, outings, sleep habits, and computer usage (Lussier et al., 2018). Studies also showed that older adults and their ecosystem are generally favorable to home monitoring and that staff is ready to change their practice accordingly (Bowes & McColgan, 2013; Peek, Wouters, Luijkx, & Vrijhoef, 2016).

According to Siegel and collaborators (Siegel, Hochgatterer, & Dorner, 2014), AAL monitoring is highly suited to optimizing supportive actions by care organizations such as social and health care services. However, despite the potential and general interest in AAL monitoring, it is mostly absent from the clinical context aside from research initiatives (Peek, Wouters, Luijkx, & Vrijhoef, 2016; Schulz et al., 2015). Also, funded large-scale studies rarely published on the efficacy and effectiveness of these systems (Calvaresi, Cesarini, Sernani, Marinoni, Dragoni, & Sturm, 2017; Hamdi, Chalouf, Ouattara, & Krief, 2014). Commercial technologies, as well as technologies developed in research initiatives, are often developed without a proper understanding of the specific needs of older adults or what clinicians consider useful. Therefore, there is a high risk that these technologies are abandoned. Because of such usability and accessibility challenges, Queirós, Silva, Alvarelhão, Rocha, & Teixeira (2015) stated that AAL research teams must be composed of interdisciplinary experts and that all stakeholders need to be actively included in all stages of development.

The study setting

In Canada, the public social and health care system is under federal jurisdiction. However, provinces, rather than the federal government, are responsible for home care program orientations. In the Province of Quebec, all public health and social services institutions are affiliated through a network of Integrated Health and Social Services Centres (IHSSC). IHSSC are administrative structures 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 with local community service centres (CLSC). CLSCs offer front-line health and social services, including home care through dedicated programs. Since 2003, the Quebec Ministry of Health and Social Services has promoted aging in place through a policy known as "Home: The First Choice" ("Chez soi: Le premier choix") (Ministère de la santé et des services sociaux du Québec, 2003). For some individuals, staying at home is a more difficult endeavour. According to the director of home care division at one of the IHSSC in Montreal (Quebec) involved in the present project, home care recipients at risk of self-neglect tend to be institutionalized more quickly and require increased services from the IHSSC, which cannot, due to a lack of resources, meet all of its needs. In Quebec, it is estimated that this clientele represents approximately 50% of the recipients in-home care in some areas of Montreal (Base de données du Ministère de la santé et des services sociaux du Québec, 2016).

The use of AAL technologies has not yet been integrated into the social and health care system in Quebec. We observe that home care division administrators are increasingly open to offering AAL as part of services for maintaining older adults at home when facing a major loss of autonomy. However, only a few AAL technologies have been implemented in a real-life setting and little information is available about how AAL technology would be implemented and used by a health care professional in the community (Hamdi, Chalouf, Ouattara, & Krief, 2014). According to a human factor approach, to be successfully implemented, technologies must fit the physical and cognitive abilities of the care recipients but must also fit well with the organizational characteristics (i.e., a team of clinicians, responsibility structure, decision-making process, political level) (Vicente, 2013).

Objectives

The present study originated from a request by management of one of the IHSSC home care division of Montreal. They asked our research team to collaborate on the development of innovative technology-based approaches to improve the support provided to home care recipients who are at risk of self-neglect. Prior to this

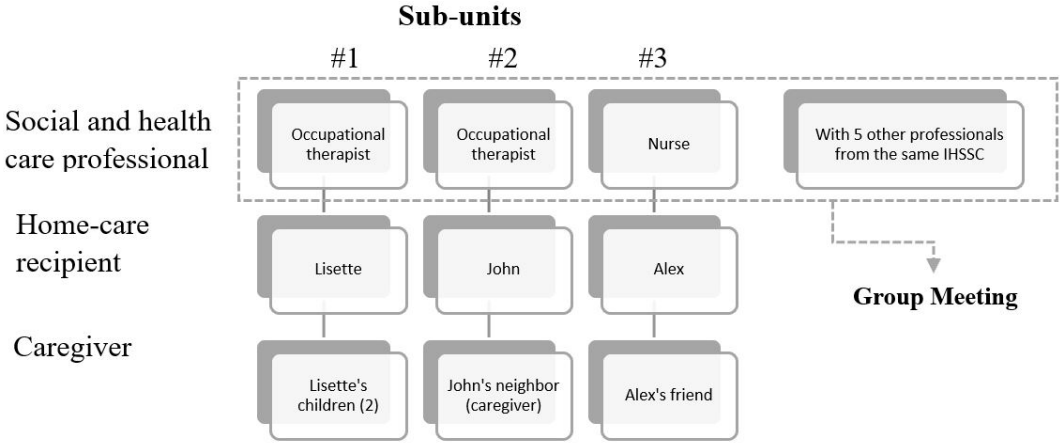

Figure 1. Sub-units within the selected IHSSC home care division

study, group interviews were held with IHSSC administrators, head of services, social and health care professionals (nurses, occupational therapists, and social workers), to help pinpoint their perception of home care as well as their expectations and needs in terms of technological solutions for this population of care recipients. 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 are functioning in their homes towards helping professionals determine which services should be put in place. In light of these expectations, the research team suggested that AAL monitoring technology could be used to detect daily patterns related to eating, sleeping, personal care, inactivity and going outside.

Empirical data on integrating technology in a real-life setting is scarce (Hamdi, Chalouf, Ouattara, & Krief, 2014), especially in the context of home care services, and there were no indications on how monitoring data would be integrated into the decision-making process of social and health care professionals responsible for care recipients. It should be noted that, in general, studies show that older adults are in favor of using home support technologies (Pol et al., 2014). Peek, Luijkx, Rijnaard, Nieboer, van der Voort, Aarts, van Hoof, Vrijhoef, & Wouters (2016) have shown that the adoption of AAL technologies depends on the personal, social and physical context of the intervention. Peek et al. therefore argue that it is important to consider the particularities of the context to ensure that the technology will be adopted and used. Therefore, the present revelatory embedded single-case study aimed to understand how and why monitoring technologies are integrated into the clinical decision-making process of social and health care professionals within the home care division of an IHSSC in Montreal (Quebec).

Methods

Design

A case-study design is relevant when the research question requires a comprehensive description of a social phenomenon (Yin, 2014), as it is the case here studying clinical decision-making in home care. We used a revelatory embedded single-case study to address the study's objectives. The rationale for this single-case study was to determine how AAL monitoring technology was integrated within the home care services offered by an IHSSC. For Yin (2014), this type of design is appropriate to obtain descriptive information about a phenomenon previously inaccessible for empirical study. Because more than one level is involved in the present analysis, this design will be embedded as shown in *Figure 1* (Yin, 2014). First, the single-case was the home care division of the IHSSC where the monitoring technology was integrated into one CLSC. This CLSC was selected by the administrators because it has the highest proportion of individuals at risk of self-neglect and living alone among all affiliated centres. Social and health care professionals from that CLSC (n = 8 in total) met as a group with researchers on three occasions (*Table 1*, data-set 1) to discuss their perceptions of AAL monitoring technology.

Second, three sub-units comprising a home care recipient, his or her caregiver and an assigned social and health care professionals were followed in detail to elucidate how the phenomenon evolves at the clinical decision-making level. As shown in *Table 1*, multiple data collection methods were used for triangulation purposes, including (1) three group interviews with social and health care professionals; (2) care recipients'

Table 1. Data sets descriptions

Data sets	Data collection methods
Data set 1 - Social and health care professionals use of monitoring in home care (including but not limited to professionals from the 3 sub-units)	2017-06-14 – Recordings of the first follow-up meeting (n=5) 2017-10-25 – Recordings of the second follow-up meeting (n=5) 2018-01-12 – Recordings of informational preferences focus group (n=4), and with one professional met individually on 2018-02-21
Data set 2 - Care recipients' profiles (3 sub-units)	Medical records Diagnostic MoCA Mini-Mental Examination State (MMSE) Iso-Smaf Service use Cognitive evaluation Rey Auditory Verbal Learning Test (RAVLT) Montreal Cognitive Assessment (MoCA) Trail making test (TMT) London Towers DKEF Stroop Test Functional evaluation Activity of daily living Profile Disability Assessment for Dementia (DAD) Security Evaluation Grid, Self-neglect severity scale (SSS) Fall Efficacy Scale (FES) Pittsburgh Sleep Quality Assessment (PSQI) Time Up and Go (TUG) Mini Geriatric Depression Scale (Mini-GDS)
Data set 3 – Monitoring data from the client's home (3 sub-units)	Motion sensors Contact sensors Electric sensors

medical records and cognitive and functional evaluations; and (3) encrypted data from monitoring technologies. The same type of group interviews was used for both the single-case level (CLSC) and the sub-unit level. The social and health care professionals present for these group meetings included but were not limited to those involved in the three sub-units.

About a month after each monitoring technology was installed, social and health care professionals received, by email, monitoring reports detailing the general routine detected in the care recipient's home during the past month. The present study will concentrate on the outcomes of this initial monitoring report on clinical decision-making.

Recruitment procedures

The study was presented to social and health care professionals from the selected CLSC. Professionals were invited to identify home care recipients who could benefit from AAL monitoring technology. To be included, recipients had to: (1) have a loss of autonomy requiring home care services (e.g., degenerative disease, chronic illness, and cognitive losses); (2) live alone; and (3) present difficulties in terms of functional autonomy.

If the care recipient was considered eligible for the study and agreed to be contacted by the research team, a face-to-face meeting in his or her home was set up with a member of the research team to explain the project and obtain written consent. They were informed that the monitoring technology would remain in the home care recipient's place of residence unless they moved, chose to quit the project, or became ineligible. Finally, care recipients were asked if they had a significant caregiver and if they would give the research team permission to contact them in order to participate in the study.

The project was approved by the CRIUGM Ethics Review Board (CER VN 16-17-22). All of the participants signed a consent form before taking part in the data collection process.

Table 2. Individual and group interview questions

Question	Content
Types of information that are relevant for practice	
1.1	Can you describe the type of information that is relevant in the context of making decisions about home care for vulnerable seniors?
1.2	According to you and your experience, what type of information can technology provide regarding home care for vulnerable older people?
Preferences regarding information transfer	
2.1	How do you prefer to receive the information collected by technology related to the home support of vulnerable seniors?
2.2	In your opinion, what are the obstacles to the transfer of information collected by technology related to the home care of vulnerable elderly people?
2.3	In your opinion, what are the elements that facilitate the transfer of information collected by technology related to the home care of vulnerable older people?
Conclusion	
3.1	In closing, would you like to add something else to our conversation? Do you have any questions?

Data collection

Data set 1 - Social and health care professionals' use of monitoring in home care (single-case and sub-units)

Two group meetings and one focus group at the CLSC were set up with the eight social and health care professionals to gather information regarding the implementation of the monitoring technologies and utilization of this technology by the professional. The purpose of the meeting was to let the social and health care professionals speak freely about their experience using the monitoring technologies in their practice. Meetings were recorded and lasted an average of 90 minutes. These meetings were moderated by one of the principal investigators (MC or NB), the research coordinator (CL) and a postdoctoral fellow (ML or MM). As mentioned above, meetings included but were not limited to social and health care professionals from the three sub-units. In one case, one of the professionals could not attend the focus group, but the researcher (MC) did an individual phone interview with her. Interview questions are presented in *Table 2*. This data set was used at the single-case (CLSC) as well as the sub-unit level.

Data set 2 - Care recipients' profiles (Sub-unit)

Following consent, home care recipients were evaluated by a research professional (occupational therapist). Data collection took place over two to eight meetings (according to their needs), via questionnaires (*Table 2*). This information was used in this paper to better describe care recipients at the sub-unit level.

Data set 3 – Monitoring data from the care recipients' homes (n=3): (Sub-unit)

For this study, a set of wireless sensors was placed in different parts of the user's home to monitor sleep, going out for activities, time spent inactive, cooking-related activities and hygiene-related activities. Three types of sensors were used: passive infrared (PIR) sensors, magnetic contact sensors, and smart electric switches. PIR sensors were installed in the bedroom, kitchen, dining room, living room, entrance, and bathroom. One or two sensors were installed in each room depending on the size and layout of the room. Two sensors were always installed in the bedroom: one aimed toward the bed and another toward space in between the exit and the bed. Other sensors were installed in a location that occupants would necessarily pass when entering the room. PIR sensors were used primarily to determine room occupation. *Figure 2* presents an example of PIR sensor distribution within the home. After a PIR sensor was triggered in one room, the occupant was considered to occupy this room for as long as the PIR sensor in another room was not triggered. Magnetic contact sensors were used if various storage apparatus or doors were being opened. For all apartments, a contact sensor was installed on the front door and one drawer or wardrobe used frequently (i.e., underwear drawer). In the kitchen, the location and number of sensors varied depending on the layout and the occupant's routine. The refrigerator, utensil drawer, kitchen cabinet, and one food storage cabinet were always equipped with sensors. The freezer, kitchen cabinet, and food storage could also be equipped if possible and relevant, according to the occupant's self-reported routine. Finally, smart electric switches were installed on the television and the microwave. The oven, toaster, coffeemaker and bedside lamp could also be monitored if possible and relevant, according to the occupant's self-reported routine.

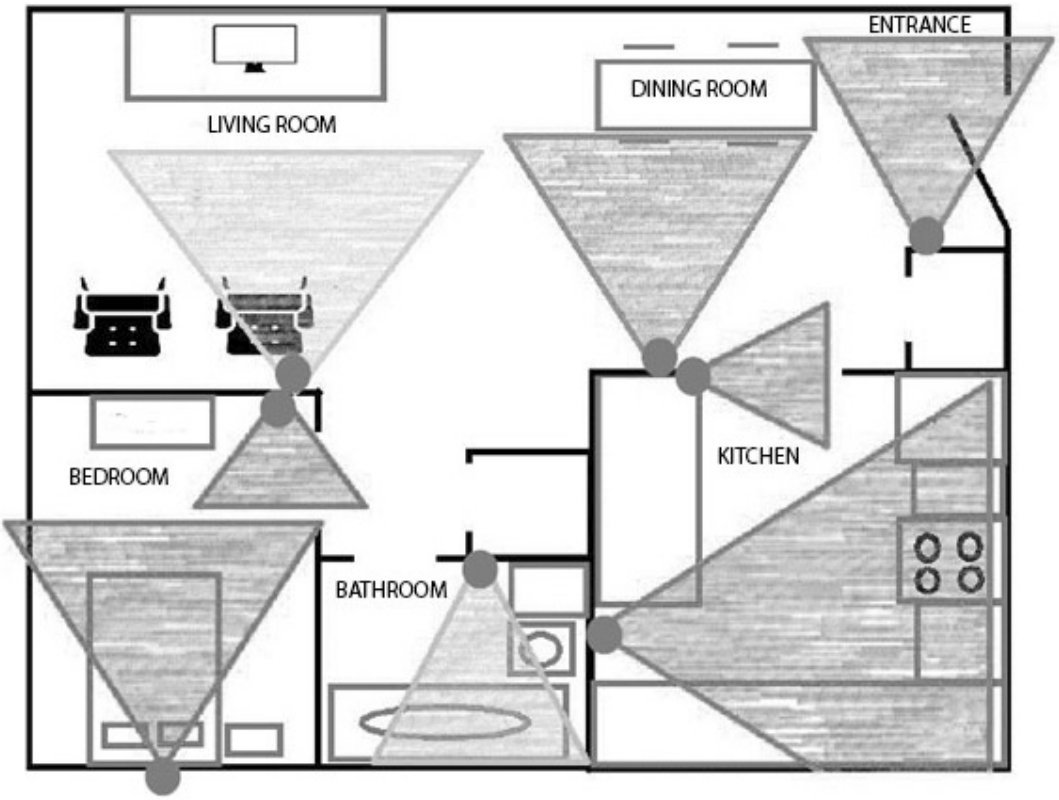

Figure 2. Example of motion sensor distribution within the home

Wearable sensors were ruled out of the present study because currently available technology has short battery life and must be removed daily. This can lead to poor acceptability and poor compliance especially in older adults with cognitive deficits that have difficulties rigorously charging and wearing the technology (Baig, Gholamhosseini, & Connolly, 2013; Mahoney & Mahoney, 2010; Patel, Park, Bonato, Chan, & Rodgers, 2012). Moreover, wearable sensors present more challenges when it comes to the cultural stigma of weakness and dependency (Patel, Park, Bonato, Chan, & Rodgers, 2012). Interviewed health care professional mentioned that several of their care recipients already had such technology, but rarely wore them.

For all participants, based on the data gathered from wireless sensors, algorithms were developed to monitor sleep, going out for activities, time of low levels of activity, cooking-related activities and hygiene-related activities. Algorithms were built around assumptions about these different activities. Sleep time assumptions were determined by a significant amount of time spent in the bedroom with a minimal amount of movement in the room. Duration of an outing assumption was that the occupant was out when the time between the front door closing and re-opening was longer than five minutes and no sensors were triggered in the house during that time. Low activity assumption was determined if the occupant was not sleeping or out, and no PIR sensors or magnetic contact sensors had been triggered for a period of more than 15 minutes. Cooking activities (i.e., cooking, doing dishes, putting away groceries) assumption was determined by the detection of the occupant spending a significant amount of time in the kitchen but also triggering contact and/or electric sensors in the kitchen. Hygiene assumption was that hygiene-related activities (i.e., brushing teeth, showering, going to the toilet) were being performed if the occupant spent a significant amount of time in the bathroom. For the sleeping, cooking and hygiene activities, a threshold of significance was calculated for each occupant based on all previous data recorded for them (two standard deviations from the mean level of activity). Put simply, an occupant known to cook simple, quick meals were considered to have a low threshold for cooking, while someone known to cook elaborate meals would require more activity in the kitchen to be considered to be cooking. This was done to reduce "noise" and consider only activities that were significantly important in the context of that user's daily behaviors.

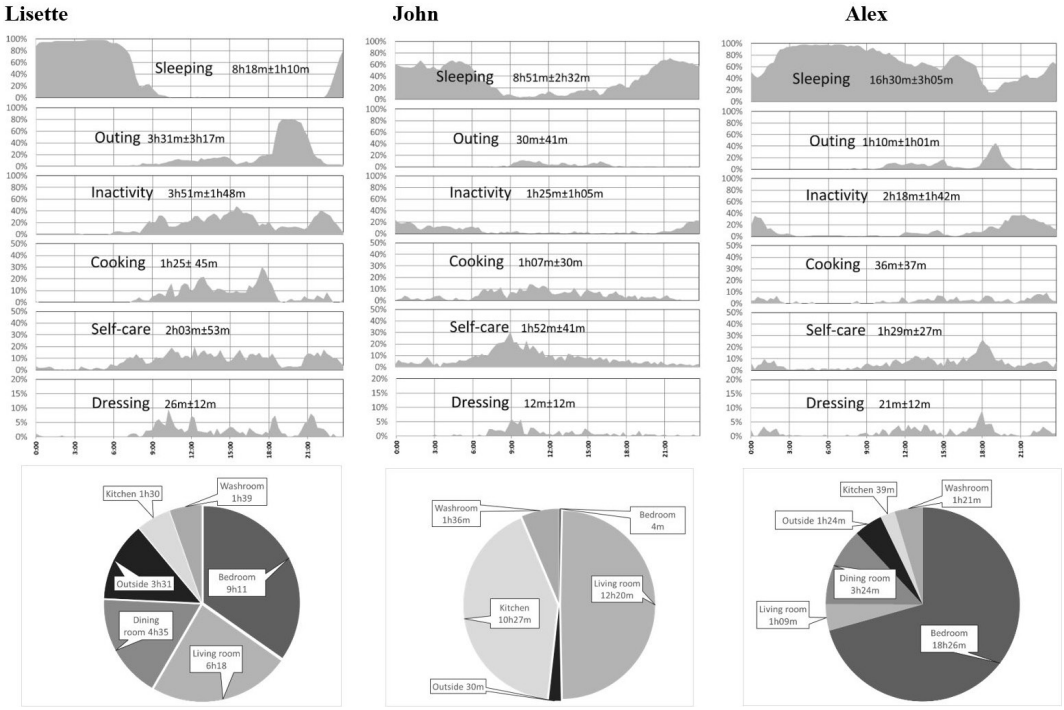

Figure 3. Excerpt from the Ambient Assisted Living monitoring reports

As mentioned earlier, monitoring reports were sent by email to the social and health care professionals' part of the three sub-units after about a month of monitoring was completed. Examples of reports for each care recipient are detailed below.

Data analysis

Qualitative data from recordings of the two meetings, the focus group, and the individual interview 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 (2014). More precisely, two processes were used: codification and matrix building. First, descriptive codes were created, which labeled units of text (words, sentences, paragraphs) that encompassed a distinct meaning with regard to how and why monitoring data was used by social and health care professionals in the home care department of the IHSSC. 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 a postdoctoral fellow (MM) and revised by a researcher specialized in qualitative research (MC). Second, matrices were used to further analyze the decision-making process of social and health care professionals according to the following aspects of the phenomenon: why professionals requested the monitoring for their client, which information they used, how it was integrated into the intervention plan and the perceived benefits of using a monitoring in their practice. Matrix-building was done jointly by the researcher specialized in qualitative research (MC) and another postdoctoral fellow (ML) (*Figure 1*).

Results

First, results regarding how and why monitoring technologies were integrated into the decision-making process of social and health care professionals will be explained. Then, the integration process for each of the three home care recipients' cases will be described. Finally, a model for integrating AAL monitoring within the clinical decision-making process will be presented.

Individual description of integrating monitoring technologies within the clinical decision-making process

For each case, the pre-implementation context is described, followed by an overview of pre-implementation concerns leading to the integration of technology, and finally a summary of the utilization of monitoring data made by the social and health care professional. *Figure 3* shows an excerpt from the AAL monitoring reports for each recipient.

Lisette's case

Context

Lisette was a 91-year-old female at the time of the study. She has been living in the same one-bed-

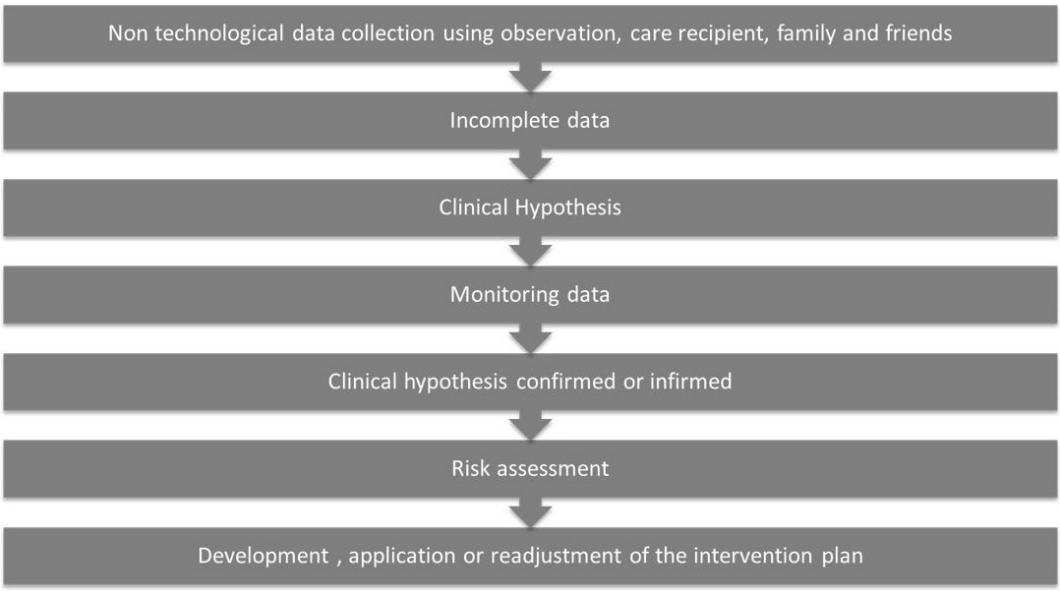

Figure 4. Model of integration of ambient assisted living monitoring technologies within clinical decision-making

room apartment for the last 14 years and has been widowed for several years. Her son and daughter visited about three times a week, and her son was the main caregiver and contact for the health care providers. In 2017, she was admitted to the CLSC home care program secondary to a fall that caused hospitalization for a rib fracture with subarachnoid hemorrhage and associated loss of autonomy. A delirium occurred during hospitalization (MMSE 17/30 and 21/30 post-delirium). She had previously been diagnosed with various heart problems and had been wearing a pace-maker since 2016. A diagnosis of Alzheimer's disease was given in 2015, but a vascular etiology was also considered. Following her hospitalization, Lisette refused to participate in the hospital daycare center activities. She also wished to continue living in her apartment with assistance, because she has been there for several years and has developed a social network in the building.

Pre-implementation concerns leading to the integration of technology

Lisette was included in this study of home monitoring technology because her care professional's main concern was a risk of malnutrition. This had been reported in her medical files, along with the fact that her weight was below average. She reported that she sometimes skipped meals and doesn't eat much for breakfast. Relatives sometimes provided groceries and made sure she had frozen meals. Her family members agreed that she'd had a small appetite for many years, but in recent years, they often found evidence of her not eating even though she said she did (food rotting in the refrigerator, lack of dirty dishes, etc.) and they were worried. Lisette's care professional wished to better understand Lisette's eating habits and determine which services would be the most appropriate for her.

Also, the son was worried that his mother might start a fire using the oven because she had recently left the kitchen faucet turned on and unattended for several hours. The landlord also shared this concern and stated that he would like to unplug the oven, but Lisette refused and insisted that she needed it. The care professional was somewhat skeptical that Lisette was still using her oven regularly and wished to monitor its users to better assess the risk level.

Finally, Lisette's care professional wished to have a clearer view of Lisette's hygiene habits because she had some concerns but needed to clarify whether more services were necessary.

Utilization of monitoring data by social and health care professional

According to the monitoring report (see *Figure 1* for an extract), about 1h31m per day was spent performing activities related to meal preparation such as warming dishes in the microwave oven, opening the refrigerator, washing dishes and putting away the groceries. Meal related activities were spread out between 10:00 AM and 1:00 PM and, also, more markedly, around 5:32 PM. The microwave was used for about 6 minutes per day and was not used at all on 20% of days during the first month. The oven was only used for 11% of days, for an average of 20 minutes on those days. The fridge was used a few times each day. Over-

all, food and dishes cabinets and drawers were scarcely used and rarely in combination with one another. The care professionals mentioned that Lisette's monthly weight had stayed stable for a few months. She concluded from the monitoring report that Lisette was eating regularly but only simple snacks. Indeed, the minimal usage of the microwave and oven suggested she rarely ate hot meals. This and the generally low level of interaction between kitchen sensors led Lisette's care professional to believe that she was only having snacks (e.g., a banana, cookies, wrapped cake, chips, etc.), but ate enough to maintain her weight. In conjunction with all the information at her disposal, the professional decided to wait before including a prepared meal service. Instead, she recommended that Lisette receive vitamins and nutritional supplements. Her son would provide her protein meal replacements and would try to make sure that she drank them regularly. As well, the professional found it interesting to learn that breakfast was possibly often skipped because this meal was supposed to be prompted by the personal care assistants who supervise medication intake each morning. A follow-up on the efficacy of that intervention was planned.

Regarding the oven-related hazards, the minimal and contained usage of the oven reassured the care professional about the fire hazard. Since disconnecting the oven would be confrontational for Lisette, regular changes/checks of fire detector batteries were recommended for the moment.

Regarding hygiene, Lisette spent about 1h44m active in the bathroom on weekdays with a significant increase of activity on Saturdays (2h42m) and Sundays (3h08m), primarily prior to leaving the house for 2 to 3 hours. For the rest of the week, activity was distributed relatively homogeneously throughout the day. Finally, Lisette spent about 23m getting dressed mostly around 10:20 AM, 6:29 PM, and 9:20 PM, so, generally a little bit after waking up and then before and after going out in the evening. Lisette's care professional was reassured upon observing that, on weekends, Lisette was significantly active in the bathroom for longer periods of time. Since Lisette went dancing each Sunday, her care professional deduced that such activities were a motivation to self-care. She noted that, if Lisette were to become unable to participate in the dancing or bingo activities, following up on hygiene habits would be advised.

John's case

Context

At the time of the study, John was a 49 years old man, living alone in a low-rent housing unit in Montreal since 2015. He had multiple sclerosis and circulate in his apartment in a wheelchair. He had lost most contact with his relatives and his community because of his sexual orientation, and his only caregiver was an immediate neighbor. This caregiver was feeling exhausted and wished to be freed from these responsibilities.

In 2010, he was diagnosed with progressive primary multiple sclerosis (MS) causing physical, sensory and cognitive impairment. He also had anxiety disorders leading to difficulty when dealing with unusual, complex or learning situations. He had consumed large quantities of cannabis and tobacco for a long time and had been diagnosed with chronic obstructive pulmonary disease. He wished to continue living in the same apartment.

Pre-implementation concerns leading to the integration of technology

At the time of the pre-implementation phase, a few incidents had occurred: John felt on the floor, bedsores appeared, and some meals had been left untouched. Moreover, the professional suspected that his cannabis consumption, which was controlled and stable, might have increased significantly recently. Since his disease was degenerative and because he was prone to apathy and anxiety, John's care professional was worried that John may not be performing his daily self-care activities regularly, especially showering. During her visits, the care professional found John vague and unwilling to comment on his daily routine. With the absence of a nearby caregiver, it was harder to get a clear idea of how John fared in his daily activities. So the care professional believed that home monitoring technology could help determine what his daily routine was and help refine the evaluation.

Utilization of monitoring data by social and health care professional

According to the monitoring report, John spent about 8h51m sleeping, mostly between 7:00 PM and 7:30 AM. However, there were several visits to the kitchen and to the bathroom throughout the night. About 30m per day was spent outside of the apartment, mostly between 9:11 AM and 4:50 PM. The time of inactivity was about 1h25m and mostly detected during the night. About 1h07m per day was spent performing meal preparation related activities. The microwave was used only half the days of the month, for about 4 minutes per day, and the refrigerator was used every day. An average of 1h52m of activities in the bathroom was detected with significantly more activity around 9:00 AM. Similarly, an average of 12m of dressing activity was detected around 9:00 AM.

For John's care professional, the idea was to gather evidence that he was regularly active in the bathroom in the morning, which would suggest that he took care of his hygiene. Since John

was not interested in receiving support for this, his professional did not insist on adding a service. In addition, the report was consistent with several of the professional's impressions, namely that John rarely left the apartment and that he possibly spent most of his time watching television and smoking in front of the kitchen sink. This raised concerns for the care professional since John regularly woke up during the night to go to the kitchen, possibly to smoke. Since John has shown interest in using and smoking less, interventions will be proposed. John's care professional also concluded that John probably did not cook anything, simply reheating the prepared meals he received, since there was very little sensor-based evidence that he cooked. This reinforced the importance of John receiving prepared meals.

Alex's case

Context

Alex was an 87-year-old man, living alone in Montreal in a residence for seniors for the past two years. He has been living in residences for the last ten years. He has been a widower since 2010 and had no children. He had two friends who were his caregivers. Alex had numerous health issues (hypothyroidism, anxiety, depression, insomnia, bronchitis, secondary polycythemia, Paget's disease, hypogonadism, an inguinal hernia, a cholecystectomy, carpal tunnel syndrome, cataracts and history of rectal cancer) and required regular medical monitoring. He had cognitive deficits but no specific diagnosis. At the time of the study, Alex wished to live at home independently for as long as possible.

Pre-implementation concerns leading to the integration of technology

Alex seemed unreliable when asked about his daily routine. It was unclear whether it was because of a desire to please, anxiety, depression, or cognitive deficits, but there was a discrepancy between the routine he described and the routine that was inferred from visits, phone calls and comments from the neighbours. According to Alex, he went to sleep around 11:00 PM and woke up around 9:45 AM. He also napped during the day. However, each time the nurse visited, Alex was in bed. The care professional often seemed to wake him up when he called. Alex said he was eating twice a day, almost always at a restaurant. According to a local waitress, he indeed occasionally ate at the restaurant for dinner but was rarely seen for breakfast/lunch. Alex was not interested in meal preparation services or receiving housecleaning services. Recently, Alex had been losing weight. His relative also mentioned that he seemed disoriented when he went outside.

The nurse's intuition was that Alex spent more time inactive or sleeping than he reported, and so he wished to have a clearer view of the frequency of outings as well as the time spent sleeping or being mostly inactive. He also wished to know if and when Alex ate, to determine if he required more encouragements to eat.

Utilization of monitoring data by social and health care professional

According to the monitoring report, Alex stayed in his bedroom for about 18h26m per day, of which 16h30m were recognized as sleeping (minimal movement in the room). He seemed to sleep especially from 2:00 AM to 11:26 AM. However, he was detected to be mostly immobile (could be reading, watching television or sleeping) in the bedroom during most of the rest of the day. He was most likely to be outside the bedroom between 6:10 PM and 11:00 PM and around 00:30 AM. Alex went out of the house for about 1h10m per day. He mostly went out from 6:30 PM to 7:36 PM. Only 36m per day was spent doing meal-related activities. There is not a precise moment of the day when meals occurred. The microwave was only used 10% of the days for about a minute. The refrigerator was only used on 51% of days for about 2 minutes. There was no oven use. Alex spent about 1h29m being active in the bathroom and about 21m dressing. These two activities occurred more frequently around 6:00 PM, just before going out (*Figure 1*).

For Alex's care professional, the report reinforced certain hypotheses. First, it confirmed his hypothesis that Alex spent a lot of time resting in bed. He wondered if Alex was often out because he did not answer the phone, but the report would suggest that Alex was sleeping or simply did not wish to answer the phone. At least the care professional was reassured that Alex did often dress up and was active in the bathroom, generally before going out for dinner. Regarding meal preparation, the care professional concluded that Alex did not cook as regularly as he stated since he barely spent anytime interacting with the kitchen sensors. Still, in accordance with the interaction reported with a local waitress, Alex often went out to eat dinner at a local restaurant, which was consistent with the detection of outings around 6:00 PM.

In conclusion, the professional hoped that Alex's medication could be revised so that he could have more energy and spend less time in bed. Alex was invited to reconsider receiving meal preparation services as well as housecleaning services.

Overall description of the integration of monitoring technologies within the clinical decision-making process

After receiving a monthly monitoring report by email, social and health care professionals identi-

fied how they actually integrated the technology in their clinical decision-making. The professionals explained that AAL monitoring technology was being used to assess and manage risks involved in maintaining the care recipient at home. For example, the three sub-cases illustrated risks related to self-neglect such as malnutrition, deficient hygiene, not doing domestic chores, oversleeping, and social isolation. In other words, it was used to assess how safe it is to leave the person at home and what services can be put in place to make it safer. Monitoring data was used: (1) as a complement to their own evaluation of the situation and risks of maintaining the care recipient at home; and (2) to develop, apply and readjust the intervention plan.

Professionals explained that the information regarding the home care recipient's life habits provided via technology was paired to their own evaluation of the situation using the standardized forms (OEMC), an instrument that facilitates translating requests into needs, translating service needs, and allocating available resources accordingly. It provided information on daily patterns related to eating, sleeping, personal care, inactivity, and going outside. Professionals still thought it was important to do home visits for additional data such as weight and blood pressure, for example, and getting an overview of the care recipient's situation by direct observation.

Often, data was used to validate what the clients were saying about their own life habits, as their recollection of events is not always reliable due to cognitive deficits. One professional explained how technology was useful in this context:

"*When we listen to what the gentleman is saying, he assures us that he goes out for lunch and in the evening. When we arrive at his house at 10 am, he is in bed. At 1 pm, he is in bed. At 3 pm, he is in bed. It is obvious that he does not go out. He talks about his recollection of past habits. For him, that is what he is doing, his routine. So it helps us to say: No, that is not what is happening.*" (H, second follow-up meeting).

Monitoring data also helped professionals to detect changes in life habits using objective measures over many months. Patterns were identified as well as changes in those patterns, as a professional explained:

"*The biggest changes we notice were outings. We saw a reduction when we looked at the new report for August and September. There is a reduction in number of hours compared to other months. There were three per month and now it's more one to two.*" (P5, second follow-up meeting).

"*When faced with information regarding a change in routine, professionals went back to the care recipient to ask follow-up questions and clarify the situation. Changes are not always a sign of functional decline; they can also result from a conscious choice, as this example shows: "She stopped going dancing because they changed the band's singer and she was angry! (laughing). She was boycotting the dance.*" (P4, second follow-up meeting).

A big part of the social and health care professionals' evaluation is centered on risk management at home and is the basis for the development, application, and readjustment of the individualized intervention plan. According to the social and health care professionals, before introducing the technology, some services were added mainly to collect additional data about care recipients' life habits:

"*When we want more surveillance, we add more services because each person in the care recipient's home is surveillance. We try to allocate services in the morning and for lunch, etc. (…) All these people that go inside the home observe indicators. Of course, with the technology that gives us indicators on some elements, we don't have to put in place some of these services.*" (H, second follow-up meeting).

As the following excerpts illustrate, monitoring data can actually show that risks are not as great as the professionals initially believed and this changes the intervention plan:

"*We had planned to integrate meals services because we thought that this woman did not eat. She said that she was eating, but we were monitoring her weight and other things. With monitoring, we could see that she was eating. These services were unnecessary as she was eating after all.*" (P8, second follow-up meeting).

As an end result, the monitoring data contributed to the decision-making process regarding whether or not the care recipient can stay at home independently and safely. A social and health care professional explained to the research team in an interview about how the monitoring data was useful in that manner:

"*The information, especially for my patient regarding risks and dangers that made her doubt that she could stay at home, she demonstrated that she could. You saw that it was possible with the (monitoring) data that you generated.*" (Second follow-up individual interview).

Model of the process of integrating monitoring data in clinical decision-making by social and health care professionals in home care

Results gathered in the CLSC showed a consensus on the way that monitoring data was integrated into the clinical decision-making process of social and health care professionals in home care.

In clinical practice, before developing or modifying an intervention plan in response to a change in the situation of a care recipient, social and health care professionals gather data from different sources to obtain an accurate description of the situation. They use observation at the home of the care recipient to look for evidence that may be a cause for concern for safety or well-being, and they question the care recipient as well as family and friends. From this non-technological data collection, they try to assess the risks involved in maintaining the care recipient at home.

Social and health care professionals integrate monitoring data into their assessment of the situation when they believe part of the portrait is missing due to a lack of information or unreliable information. Based on the information they have, they will develop a hypothesis regarding a potential risk that has not been adequately assessed using non-technological methods. Then, they read the monthly report to see if any activities of daily living have changed significantly for that care recipient or show an increased risk. From the data, they confirm or modify their hypothesis regarding the presence of a risk. Consequently, they can then more accurately assess the risk involved in maintaining the care recipient at home by combining information from their initial data collection and the monitoring data.

Based on their risk assessment, an intervention plan is developed, applied or readjusted by choosing which home care services can reduce the risk associated with maintaining the care recipient at home. The intervention plan is implemented by either holding on a service that would be unnecessary or giving the care recipient access to new services that better meet his or her needs in efforts to keep the person at home as long as possible.

Discussion

The present study originated from a request by the management of the home care division of an IHSSC to our research team regarding the integration of innovative AAL technologies to better understand the needs and support home-care recipients at risk of self-neglect. Consequently, within the present revelatory embedded case-study, monitoring technologies were integrated into one CLSC to provide data to social and health care professionals regarding care recipients' life habits. The study aimed at understanding how and why monitoring technologies were integrated into the clinical decision-making process of social and health care professionals within the home care services of an IHSSC in Montreal (Quebec). Monitoring reports were conceptualized by social and health care professionals as a reliable and useful source of information that helped confirm or refute their hypothesis regarding the presence of risk (malnutrition) or to develop their intervention plan (no meal support).

Results showed that social and health care professionals needed AAL monitoring when their non-technological data collection was lacking or unreliable. Individuals at risk of self-neglect have difficulties assessing their own abilities and may not always provide reliable information (Dyer et al., 2007). This type of problem may also be present for individuals with cognitive deficits or socially isolated. In this context, social and health care professionals search for more sources of reliable information to use in conjunction.

In the case of care recipients selected to receive the AAL monitoring technology, the monitoring was used by social and health care professionals for improving the choice of services by providing more accurate information for the development of the intervention plan. In addition, services were sometimes implemented only as a means of getting more information. In a context of scarce financial and human resources, technologies are perceived as a way to support the public health system to provide services to the public (Allard, 2011). However, it is still unclear in the scientific literature on how technologies can contribute to better utilization of resources. Similar to findings from Jaschinski (Jaschinski & Allouch, 2015), we observed that social and health care professionals do not wish to see human interaction being replaced and will continue interacting in person with their care recipient while using AAL monitoring technology. They used the technology not as a way to avoid visiting the care recipient, but as a way to be more confident about their hypothesis. In the present study, there are indications that monitoring data avoid offering unnecessary services or using services for observation purposes by influencing the decision-making process of social and health care professionals. The present study also suggests that continuous assessment of risk through passive monitoring sensors could delay institutionalization in some cases of self-neglect if the right services provided at the right time. This needs to be demonstrated with larger deployment.

Our results must be interpreted in light of several methodological limitations including the small number of cases investigated. As only one home care division was involved in this project, replication is needed to better assess the transferability of the present results in other environments. The technology did not allow us to monitor two individuals living in the same house, so, in the present study, all participants lived alone. Monitoring multiple individuals would be possible but would required wearable technology which was avoided because of the poor compliance of

individual who suffers from a cognitive deficit. Also, monitoring did focus on a limited number of activities of daily living. Monitoring could surely be extended to numerous other activities (e.g., medication management, moving into the house, leisure activities). Still, the monitoring reports were perceived as useful and coherent with other sources of information when available (i.e., data-set 1 and 2).

In relation to clinical practice, this study helped to identify the type of information that is relevant to social and health care professionals to better assess risks and emphasized their need for reliable information regarding activities of daily living to be able to develop an appropriate intervention plan. Few studies have focused on the use of monitoring technologies by social and health care professionals in home care. While most studies in clinical setting have looked at medical information (Huikuri, Mäkikallio, Airaksinen, Seppänen, Puukka, Räihä, & Sourander, 1998; Kesek, Franklin, Sahlin, & Lindberg, 2009; Mäkikallio, Huikuri, Mäkikallio, Sourander, Mitrani, Castellanos, & Myerburg, 2001; Meyerfeldt, Wessel, Schütt, Selbig, Schumann, Voss, Kurths, Ziehmann, Dietz, & Schirdewan, 2002; Patel, Lorincz, Hughes, Huggins, Growdon, Welsh, & Bonato, 2007; Rantz, Skubic, Koopman, Phillips, Alexander, Miller, & Guevara, 2011; Thomas, Mietus, Peng, & Goldberger, 2005), our study focused on activities of daily living (eating, sleeping, hygiene, inactivity and going out). Based on our results, medical data does not seem to be sufficient for the evaluated risk associated with living at home alone. Monitoring of activities of daily living have been explored in laboratory settings, namely to predict cognitive deficit (Lussier, Lavoie, Giroux, Consel, Guay, Macoir, Hudon, Lorrain, Talbot, & Langlois, 2018), but, to the best of our knowledge, monitoring was never integrated in the professional clinical practice of social and health care professionals to get a clear and comprehensive picture of how the person is functioning at home. In addition, in this study, social and health care professionals were not told how to use the technology but rather had the opportunity to approach monitoring technologies to decide how they would best be integrated in their clinical practice.

Aside from people at risk of self-neglect, there are other populations in home care that might also benefit from a more accurate evaluation of their activities of daily living using monitoring technologies, namely, those with cognitive deficits or mental health problems. Still, these technologies must be accepted by care recipient, their caregivers as well as social and health care professionals to be useful in-home care. This project demonstrates that these groups are open to this type of technology which is in accordance with other studies (Demiris et al., 2004; Mihailidis, Cockburn, Longley, & Boger, 2008; Peek, Luijkx, Rijnaard, Nieboer, van der Voort, Aarts, van Hoof, Vrijhoef, & Wouters, 2016; Pol, van Nes, van Hartingsveldt, Buurman, de Rooij, & Kröse, 2014).

Deployment of AAL monitoring technologies in the care recipient's home can be challenging. The technology must be robust, reliable and, especially, flexible enough to operate in widely different home spaces for the individual having heterogeneous activities of daily living. Here, we were able to do so without using an overabundance of sensors since activities were examined over a large period of time (a month) and to extract global patterns. We used a passive monitoring as it is one of the most inclusive solutions. Indeed, because it does not require any knowledge of technology, it can be used in spite of cognitive decline. Also, it is robust to sensory and motor decline and it does not need to be translated into multiple languages. In addition, instead of sending various staff members at home of care-recipient for observation, which can be intrusive for the care recipient, the information is passively gathered through sensors that are hidden in the surroundings. Only the professionals need to be instructed on how to read the monitoring report (not the care recipient or the caregiver) and a single professional can be in charge of several care recipients monitoring reports. Still, the data is complementary to the clinical evaluation by professionals.

Each sub-unit from the present study will be followed for about a year and longitudinal usage of the monitoring data will be examined. In parallel, the monitoring report presentation is being upgraded from a word processor format to a secured Web-based platform for dynamic and easier access. Our research team is also working toward the implementation of the technology that is independent of the researchers' works so that this tool continues being used by clinicians once the research project is over. Finally, an economic analysis is currently being done to better determine 1) what is the estimated cost of integrating such a monitoring technology into the health care system and 2) what are the economic benefits, if any, of better optimizing resources and delaying institutionalization of care recipients. While the cost-effectiveness of this technology as yet to be demonstrated, the level of interest shown by the health care professional is promising so far.

Conclusion

This study showed that AAL monitoring technologies provide social and health care professionals relevant information that would otherwise be in-

accessible and help them to develop an individualized intervention plan. This type of technology is conceptualized as a means of better fulfilling the needs of the clients as well as using social and health care resources wisely in a context where resources are scarce. More studies are needed to replicate the results of this study and evaluate the impact of using AAL monitoring technologies within public social and health care systems.

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