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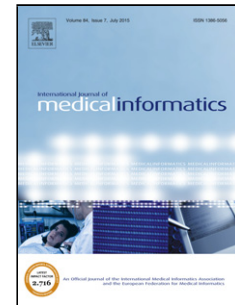
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### Highlights

- In-home activity monitoring of older adults with dementia can provide important information to home care nurses, particularly during night time
- Activity information can assist home care nurses to identify wandering behaviours, plan night visits, and ensuring that seniors get enough sleep
- Various factors influence nurses' adoption of in-home monitoring technology and nurses' involvement in the design and deployment process is important

# Integration of an in-home monitoring system into home care nurses' workflow: A case study

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## Abstract

**Background** The healthcare system faces a major challenge in caring for an increasingly ageing population as this task requires more resources than are currently available. Adopting monitoring technologies could enable more efficient care practices and support ageing in place.

**Objectives** To investigate how the use of an in-home motion monitoring system can be integrated into home care nurses' workflows and to uncover the factors behind system adoption.

**Design** A single case study adopting a qualitative approach.

**Setting** A home care unit serving older adults living in independent living residences within an apartment complex.

**Method** Multiple data collection methods were used including individual and group interviews, a questionnaire with open-ended questions, evaluation probes, and system log data. The qualitative material was analysed using a stepwise-deductive inductive approach.

**Results** A central factor behind system adoption was the perceived usefulness of gaining information about older adults' night-time activities. In particular, monitoring older adults suffering from memory disorders was considered advantageous. The information that the system provided supported nurses in health assessments and assisted in adjusting care decisions. Previous negative experiences with similar technologies initially influenced the time for adoption. Further, although nurses were closely involved in the system design process, they took some time to get acquainted with the system and to integrate its use into daily practice. System reliability and accuracy issues influenced nurses' trust in the sensory data.

**Conclusion** The findings suggest that in a home care setting, focusing on motion pattern monitoring for older adults with memory disorders can provide significant benefits and therefore also facilitate system adoption among nurses. Involving nurses in the design of the technology and providing opportunities to trial the system in real practice also appear to be important in achieving system adoption.

**Keywords:** in-home monitoring, home care, nursing informatics, qualitative research

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## 1. Introduction

Our aging society puts excessive stress on home care services that are expected to care for the fast-growing number of older adults. In Europe, the number of older adults aged over 80 years is estimated to more than double between 2015 and 2080. At the same time, the working-age population is expected to decline (Eurostat, 2017), thus reducing the care resources available. In-home monitoring systems have been proposed as part of a solution by offering technological support for aging in place (Reeder et al., 2013; Jankowski et al., 2017; Mieronkoski et al., 2017). These systems use networked sensors and data processing software to detect activities of daily living (ADL), significant events such as falls, and health status changes (Majumder et al., 2017; Peetoom et al., 2015; Ni et al., 2015; Liu et al., 2016).

Liu et al. (2016) reviewed smart home technologies for older adults and found that most systems focused on monitoring ADL and provided positive economic and clinical outcomes. Similarly, Reeder et al. (2013) noted the effectiveness of systems that included an activity sensing component. Rantz et al. (2017b), through a randomised clinical trial, demonstrated the positive health outcomes of in-home monitoring technology aimed at the early detection of health status changes in older adults. Studies also indicated that monitoring systems can prolong the length of stay in independent living residences, thus supporting aging in place and reducing care costs by postponing the need for institutional care (Rantz et al., 2015; Riikonen et al., 2010). Glascock and Kutzik (2006), too, noted the potential benefits of in-home monitoring for older adults' ADL.

Studies have also investigated in-home monitoring systems from various user perspectives. Courtney et al. (2008) found that the perceived need of such systems for older adults was a major influence in their decision to adopt them. Similarly, Claes et al. (2015) reported that older adults were willing to trade some of their privacy by being monitored if it would allow them to continue living independently. Older adults also stated that in-home monitoring systems made them feel more secure and, to some extent, more independent (Johnson, 2008).

Mahoney et al. (2008) primarily focused on how to integrate in-home monitoring technology into informal caregivers' workplaces to allow them to supervise older family members while at work. They found that such systems reduced caregivers' stress. In a follow-up study, caregivers mentioned that they installed such monitoring systems to understand whether 'their family member was OK' (Mahoney et al., 2009). Johnson (2008) reported similar experiences. Skubic et al. (2016) discussed challenges in designing user interfaces that older adults can easily interact with.

With regard to formal caregivers' perspectives, an in-home monitoring system deployed at an independent living facility named TigerPlace in Missouri, USA, was developed in close collaboration with clinicians. This system uses various types of sensors (including video, bed, motion, and temperature

sensors), automatically detects health status changes, and alerts caregivers (Rantz et al., 2017a). The algorithm design was informed by clinicians to enhance the clinical relevance of the system (Skubic et al., 2015). As the system was continuously improved based on users' feedback, clinicians' perception of its clinical relevance increased over time (Rantz et al., 2017b). Clinicians were also involved in other aspects of the system design such as informing user interface design to improve usability (Alexander et al., 2011).

The above-mentioned studies investigated in-home monitoring systems from different perspectives. Nonetheless, the majority of studies within this field focus on the internal system's construction and coherence, which is often evaluated through simulations and lab experiments (Peetoom et al., 2015). Although several commercial in-home monitoring systems are available, they are yet to be widely deployed (Glascock, 2012). Thus far, few studies have investigated such systems' role in the larger socio-technical healthcare system and on how they are adopted and used by caregivers (Bowles et al., 2015). The use and integration of this new type of system into nurses' often hectic work schedules is not straightforward (Demiris, 2016; Mahoney et al., 2009) and requires careful consideration. Therefore, this study evaluates nurses' perspectives on a deployed in-home monitoring system designed in close collaboration with home care nurses. Through a case study approach, we aim to answer the following research questions: *How can an in-home monitoring system be used and integrated into home care nurses' workflows, and what are the factors that influence system adoption?*

## 2. Background

### 2.1. Adoption of technology: Influencing factors

For health services to take advantage of innovative information technologies, they need to be adopted, that is, they need to be put into use and become part of the normal practice. Toward this end, many models have been developed to explain the factors behind technology adoption (Ward, 2013). Roger's Diffusion of Innovation Theory is commonly used to explain system adoption (Rogers, 1983).

This theory has been used to analyse the adoption of various health technologies. For example, Zhang et al. (2015) used this theory to investigate the causes behind the low adoption rate of an e-appointment scheduling service. Olsson et al. (2016) used the five distinct characteristics of an innovation proposed by Rogers (1983) to analyse users' perceptions of a passive positioning alarm for persons with mild dementia.

The five characteristics of an innovation that influence the adoption rate are relative advantage, compatibility, complexity, trialability, and observability (Rogers, 1983). Relative advantage refers to how potential users perceive the innovation as an advantage over existing alternatives. For example,

relative advantage can be measured by economical or performance benefits, convenience, or satisfaction. Compatibility refers to how well the innovation is in line with existing needs, beliefs, and values of, for example, an organisation adopting the innovation. Complexity, or usability, refers to how easily the  
 70 innovation can be used and understood. Trialability refers to whether the innovation can be tested or piloted before deciding to adopt it. Observability refers to whether the results of adopting an innovation are visible to others (Rogers, 1983).

From a socio-technical perspective, user involvement in the technology design process is essential  
 75 for producing useful designs (Mumford, 2006). As the introduction of new technology will inevitably cause changes in working practices (Bossen, 2018), thus affecting end-users, we have adopted a user-centred design approach for the design of an in-home monitoring system (Ritter et al., 2014). In this approach, home care nurses were identified as key stakeholders in system adoption. Therefore, to increase the chances of the system being adopted in practice and fulfilling actual information needs, it  
 80 was developed in close collaboration with home care nurses over a three-year period.

## 2.2. Design of in-home motion monitoring solution

### 2.2.1. Understanding the context

Through ethnographically inspired fieldwork (observations, focus groups, and interviews), we found that nurses sometimes visit their home care clients infrequently and that visits are often conducted by  
 85 different nurses. This makes it difficult for nurses to maintain a good overview of older adults' health and functional abilities. Further, care plans are often discussed and decided upon together with older adults and their significant others. However, nurses revealed that information about older adults' care needs was not always trustworthy, especially if they suffered from a memory disorder.

Therefore, before the system was fully developed, nurses suggested that information could be  
 90 used to provide further insights into older adults' care needs. Two aspects were brought up during interviews, namely, that the in-home monitoring system could bring attention to previously unknown issues (e.g. wandering behaviour) and provide insights into already known issues (e.g. tiredness and fatigue) (Klemets et al., 2017).

### 2.2.2. System architecture

The proposed system has a typical Internet of Things (IoT) architecture (Mieronkoski et al., 2017)  
 95 with passive-infrared (PIR) motion sensors placed in each room of an apartment and an outdoor sensor to monitor an older adult's activities. The infrastructure allows nurses to supervise motion patterns (e.g. bathroom visits, time spent in bedroom) and to spot irregular patterns. Figure 1 shows an overview of the system architecture.

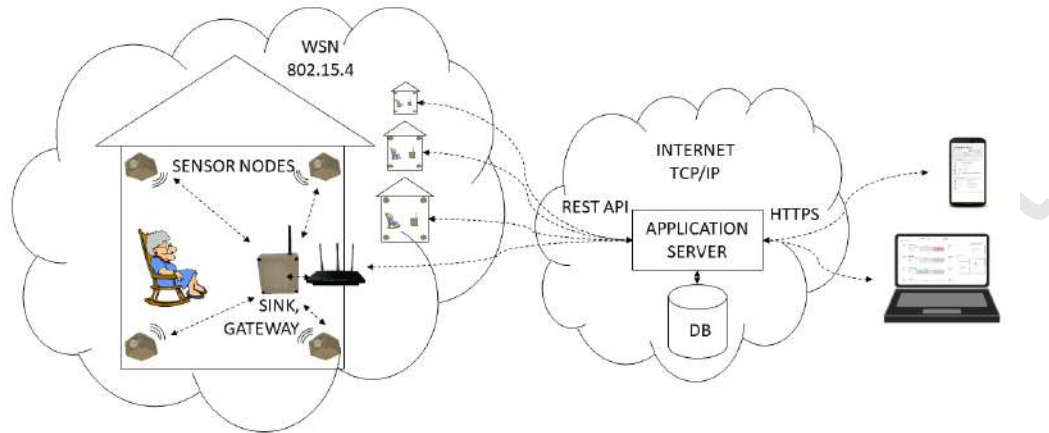


Figure 1: Overview of system architecture.

To avoid installing additional wires in apartments, the system uses wireless sensor network technology in which each sensor node communicates wirelessly with a sink node. The sink node connects to a gateway that sends the measured data to a server on the Internet.

Motion and door opening data are sent from the gateway(s) to a central server through WiFi or a 3G/4G connection. A data analysis component processes these data to identify different activities. These include the time spent outside the apartment and inside various rooms (bedroom, bathroom, kitchen, and living room) and number of bathroom and outdoor visits.

The processed data is presented and visualised through a web interface that allows nurses to access information about a client's in-home motion patterns. By logging in to the service and selecting a client from a list, the nurse can obtain a statistical overview of their activities during the last day/week/month. A graph view of the same data allows the nurse to obtain detailed spatio-temporal information about the client's in-home motion patterns.

Further, nurses receive a text message on their mobile phone each morning at the start of their working shift. The message contains information about whether any of their home care clients have been outside their apartment during the night and whether they have returned to their apartment. This functionality was added during a design iteration to address nurses' concerns about some of their clients' wandering behaviours. The message allows nurses to obtain a quick overview without having to log on to the web portal.



### 3. Methods

#### 3.1. Research setting

The case study (Yin, 2003) was conducted at an apartment complex managed by the Central Ostrobothnia Joint Municipal Authority for Social and Health (Soite) in Finland, which is intended as an independent living residence for older adults. The complex consists of around 70 apartments, and home care services are provided and tailored according to individual needs. The home care unit that served the clients had its office in the apartment complex. The complex also included a restaurant and a day room where various activities were arranged for clients. Both nurses from the home care unit and older adults living in the residences participated in the study.

The home care unit was divided into three separate teams that consisted of one registered nurse (team leader) and 3–4 practical nurses. All three registered nurses (team leaders) and the head nurse of the home care unit participated in the study. All nurses had more than 10 years of home care experience. Nurses were provided access to the in-home monitoring system. The main care responsibilities were divided among the three teams. At the start of the project, nurses at the unit were informed about the project and its objectives.

The in-home monitoring system was deployed in eight clients' apartments. Purposive sampling coordinated with the home care nurses was used when recruiting clients to the study. Nurses were thus allowed to identify clients who they thought would benefit the most from being monitored. Identified clients and their significant others were then approached in person by both the nurse and the researcher. All clients participating in the study were between 82 and 96 years old (average: 90.6 years) and received home care assistance several times a week by the home care unit. Six of these clients suffered from memory disorders to various degrees.

#### 3.2. Research design

An initial version of the in-home monitoring system was deployed in the summer of 2016 to allow nurses to become acquainted with the system and to enhance the data analysis software by gathering real-life data. Figure 2 shows an overview of the different data collection phases. Note that the data collected in 2016 (marked in a darker colour) is not included in the analysis; these results have been published elsewhere (Klemets et al., 2017). However, these data were used to inform the design of the succeeding data collection phases (marked in a bright colour) included in this study.

In the spring of 2017, semi-structured interviews were conducted separately with the three registered nurses and the head nurse with a focus on the system's use, usefulness, and possible design enhancements. Each interview lasted 30–40 min. After addressing the main issues and suggestions raised during the interviews, a new version was developed and deployed a month later.

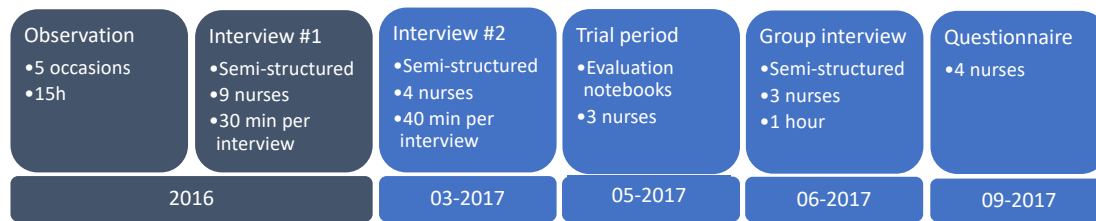


Figure 2: Different data collection phases during the project. Data collected during brighter-coloured phases are included in this study.

To study the adoption and use of the in-home monitoring system, a combination of evaluation probes, focus group interviews, surveys, and log data was used. Evaluation probes are used to evaluate technologies 'in the wild'; this originates from the idea of cultural probes that was initially introduced by Gaver et al. (1999) to understand local cultures to inspire innovative designs. Luusua et al. (2015) discussed how probes, such as scrapbooks, can be used to evaluate design artefacts from an experiential viewpoint without direct researcher presence. As we wanted to capture nurses' thoughts and reflections on the in-home monitoring system in situ, a notebook was designed that included tasks, open-ended questions, and screenshots of the system's user interface on which the nurses could make comments. Nurses agreed to use the in-home monitoring system at least two times a week over a four-week period, which meant logging in and going through the activity measurements for their clients. The notebook was kept close to the computer used to access the system, and it was to be filled in at the same time.

After the trial period, the notebooks were collected and analysed. Based on the comments and feedback, a semi-structured interview guide was developed. Focus group interviews lasting around 1 h each were then conducted with three of the nurses. The nurses commented on and clarified issues brought up in the notebooks and reflected on the benefits and drawbacks of the system and its functionalities, including the user interface and how the system was integrated into their existing workflows. Around 3 months after the trial period had ended, the nurses were sent a questionnaire with open-ended questions to allow them to further elaborate on the perceived benefits of monitoring for each client participating in the study.

The first and second authors, both of whom are experienced interviewers, conducted the interviews and focus group interview. All interviews were conducted at the home care unit's office and audio-recorded. Notes were made during the interviews. The transcribed data, notebooks, and questionnaire responses were imported into the Atlas.ti tool for qualitative analysis. The first and second authors then conducted a qualitative analysis using the stepwise-deductive inductive approach (Tjora, 2010). Data relevant to the research questions (how can an in-home monitoring system be used and integrated into home care nurses' workflows and what are the factors that influence system adoption?) were first open-coded using codes that closely resembled the original text. The codes were then sorted into

broader categories based on the coherence among them. At this stage, literature was reviewed with the developed groups in mind, and relevant theories were identified and used as a sensitising tool to further sort the code groups into five main themes. The findings were then presented and discussed together with the participating nurses to improve validity.

Ethical approval was granted by the governing body of the home care team, and signed informed consent was collected from all participating nurses, older adults, and their significant others. All collected data were anonymised during the transcription process.

## 4. Results

### *4.1. Night-time monitoring of older adults suffering from memory disorders*

During initial discussions, nurses identified older adults with memory disorders as the main target group for whom in-home monitoring could provide the greatest benefits. They explained that many such adults were unable to tell them about their struggles and how they cope with daily living. One nurse stated that 'Essentially it is those with memory disorders, as they are not able to tell you about their day, where they've been, or what they have been doing'. Nurses are available in the apartment complex between 7 AM and 10 PM but not during the night. Therefore, nurses appreciated the ability to find out more about their clients' night-time activities through the sensory data. A nurse (3) stated that 'The night time is important because patients are all on their own'.

#### *4.1.1. Identifying wandering behaviour*

Nurses explained that whether older adults with memory disorders can live independently largely depends on how well they can get through the night. Such adults commonly show wandering behaviours, and the nurses feared that they would wander outside the building and not find their way back. During the trial period, nurses explained that they developed a habit of checking their clients' night-time activities each morning when they arrived at work.

Nurses also said that some older adults with developing memory disorders sometimes sleep in their regular clothes, and in combination with sleeping in their chair (instead of their bed), the distinction between day and night is blurred. In addition, it is often bright outside during both day and night in the summer in Finland, which further adds to the confusion. Therefore, nurses said that waking up sitting in a chair while it is bright outside could increase the risk of older adults wandering outside. They found that upon identifying such cases by examining night-time activity data generated by the system, they could visit the client before bedtime to prepare them for the night.

#### 4.1.2. *Planning night visits*

The night patrol is a nursing team that makes night-time visits to some monitored clients and other older adults living throughout the city. The nurses said that the night patrol usually just peeks through the client's door to see if everything is fine. Whether the client has been active before or after the visit remains unknown. Therefore, the measured night-time activity data provide insights into when to plan these nightly visits if the client usually wakes up at a specific time. A nurse stated that 'Even if the night patrol said that the client is always sleeping, we cannot always confirm whether they are actually sleeping when we visit, for example, at midnight. The client might still be restless during the small hours; then, it would be good if someone could tell the client that it's night time and that they should get back to bed. This way, the client wouldn't wander about'.

#### 4.1.3. *Getting enough sleep*

During the interview, nurses also said that activity data helped them explain why some clients appeared more tired than usual. For example, clients' fatigue could be explained by an increased number of prolonged bathroom visits. One nurse stated that 'One new client has some bathroom issue. According to the system, she goes to the bathroom quite often, almost every hour, and she can stay there for almost an hour. This tells me that she sleeps very badly. I just had a look, and she had been in there for 40 minutes, which tells a lot'. The nurse said that after consulting a doctor about this issue, the client has now been prescribed new medication, and she was going to continue monitoring whether the intervention enabled her to sleep better.

In another case, a nurse was concerned about whether a client slept at all and was considering whether she should be moved into a nursing home. However, the nurse's concerns were addressed by the measured activity data. The nurse stated that 'I was worried whether one of my clients was sleeping at all or when she was sleeping. But now, I have confirmed that she sleeps every night for a long period. It is not always at the same time, and she often gets up in the small hours. But, I'm not concerned about it like I was before'.

Nurses were also interested in finding out whether a client spends the night mainly in the bedroom or in the living room. In particular, if they found that a client's feet were swollen, this could be explained by sleeping while sitting in a chair rather than sleeping lying down.

#### 4.2. *Perceived benefits of monitoring*

In responding to the questionnaire sent three months after the trial period, nurses reported substantial benefits in monitoring clients that suffered from memory disorders. Among the eight cases, a few illustrative ones in which the nurses used activity data for making care decisions are presented below.

*Case 1.* A 92-year-old male diagnosed with Alzheimer's disease was waiting for a place at a 24-h care home. In addition to home care visits four times a day, the night patrol visited him two times each night. The activity data revealed that during the night, he was often restless and left his apartment several times. Accordingly, the night patrol visits were rescheduled. He then started sleeping more  
 245 regularly, as confirmed by the activity data. Therefore, nurses were able to stop the nightly visits and concluded that he did not have to move to a care home but could continue living in his own apartment.

*Case 2.* An 89-year-old woman was diagnosed with Alzheimer's disease. Her relatives and nurses were unsure whether she could continue living in her apartment. By using the activity data, nurses could better understand her daily rhythm, which showed that she often went to bed early and woke up  
 250 during the late hours. By using this data, nurses could consider the 'bad' nights in her care. Based on the data, night patrol visits were stopped. Both nurses and relatives were assured that she could continue living in her apartment under supervision.

*Case 3.* A 92-year-old woman was diagnosed with Alzheimer's disease. The system was deployed in her apartment after nurses found out that she left it during the night. They noted that on some nights,  
 255 she got enough sleep, whereas on others, she went outside. However, as she always returned to her apartment and did not leave the apartment complex, nurses could postpone her move to a care home.

*Case 4.* An 87-year-old woman was diagnosed with Alzheimer's disease. She had previously had an application to move into a care home rejected. She seemed to manage well during the day, but her activity data revealed restlessness during the night. She spent a lot of time in the bathroom and did  
 260 not get enough sleep. Despite taking countermeasures, her situation did not improve. As she also started showing signs of excessive wandering behaviours, nurses concluded that she could not continue to live independently and filled a new care home application for her.

*Summary.* Nurses identified the following benefits as a direct consequence of deploying the in-home monitoring system in eight apartments.

- 265 • Nurses could establish that three clients did not have to move to a care home but could continue living in their apartments.
- A decision was made to apply for a move to a care home for one of the clients.
- Regular night patrol visits for two clients could be discontinued.

### 4.3. Integrating system use into existing workflows

#### 270 4.3.1. Reasons behind early system resistance

During the initial interviews before the trial period, it became evident that even if the system had been available to the nurses for some time already, it had not been used a lot. This was also confirmed by the system log that revealed that in a 3-month period, nurses had only logged in to the system around three times per month until March 2017 (Figure 3). During the initial interviews, 275 nurses said that lack of time was the main reason for sparse use. Nurses claimed that they were too busy in their daily work and that the many other computer systems they already had to use were too time-consuming. However, they also admitted that using the in-home monitoring system would not take a lot of time. One nurse stated that 'We have to use many different systems. We haven't had the time to get acquainted with the monitoring system'.

280 Nurses' previous negative experiences with various information systems that did not deliver on their promises also initially affected their attitude toward the in-home monitoring system. They did not expect that the new system would actually work or provide them with any useful information. One nurse stated that 'We have another alarm system that doesn't work, so we didn't think this was going to work either'.

285 Further, before the initial interview, some monitored clients were rather self-reliant, and nurses did not perceive the usefulness of monitoring them. The number of clients with memory disorders that were being monitored was too few for the nurses to perceive the benefit of using the system. Therefore, before the trial period, two additional clients diagnosed with memory disorders that had recently moved in were recruited, and sensors were installed in their apartments.

#### 290 4.3.2. Adopting system use

During the group interview after the trial period had ended, nurses' perception and use of the system had changed. During the trial period, each nurse used the system several times a week; according to the system logs, nurses continued using the system even after the trial period had ended (Figure 3). The nurses had a more positive perception of the system after the trial period ended and were keen 295 to highlight its benefits in their work. For example, when asked whether they thought the system was worthwhile, one nurse stated 'Yes, it definitely brings benefits'.

Nurses said that it took some effort to get used to the system and to understand how to interpret the graphs and numbers it provided. They felt that the trial period provided a great opportunity to get more acquainted with the system and that the notebook motivated them to learn how to use 300 it. One nurse stated 'Earlier, before working with the diary, we didn't have time to have a look. It was mostly forgotten; you could have a look now and then. But now, when we have become more

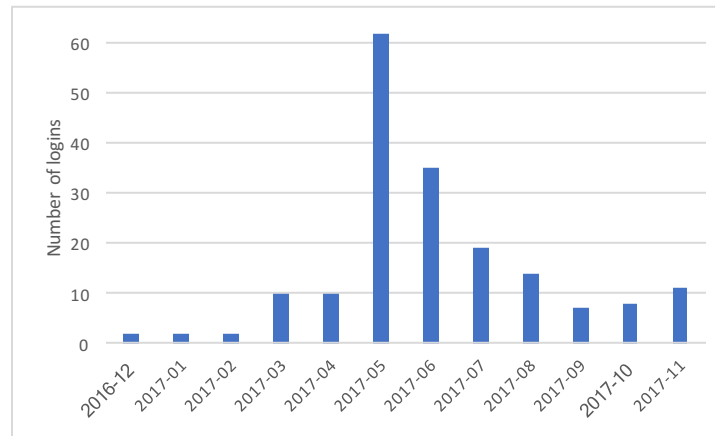


Figure 3: Number of recorded times nurses logged on each month to the in-home monitoring web portal.

acquainted, we've realised that you can get a lot of information from it. You had to learn it, but it became clearer all the time'.

In addition, the outdoor notification messages that nurses received each morning on their mobile phone enabled them to find out more about the clients' activities through the system. One nurse said that she developed a habit of always logging on to the system after receiving the text message to check up on her clients. Furthermore, before visiting their clients, nurses said that they would check the activity data first to see whether there was something requiring special attention. With regard to continued system use, one nurse stated 'I think that the system will be used more now that we have recognised its advantages'.

#### 4.3.3. Supporting a collaborative practice

Another aspect of how system use was integrated into the daily work was through collaboration with other team members. For example, a nurse wrote in her notebook: 'Discussed the new client's daily rhythm together with the team. Does she move outside alone?' and 'Went through the client's daily rhythm together and considered the activity pattern'. Although only the registered nurses had access to the system and had the main responsibility for the clients' care, issues were considered or care plans were evaluated only together with the team. In this respect, nurses thought that the activity data provided a valuable resource in making care decisions collaboratively.

Similarly, nurses also engaged with the clients and their significant others when making care plans. Nurses emphasised the value of the information provided by the system in these discussions. Further, this information also helped nurses ease the minds of relatives who were worried and inquiring about their loved ones. Nurses explained that they felt more confident talking to their clients' relatives because they now had another data source to back up their assessments.

#### 4.4. System reliability and accuracy issues

During the trial period, there were some issues with the algorithm that determined whether clients had left their apartment. For example, if the night patrol had just peeked through the door while the client was sleeping and the system did not register any movement inside the apartment after the door was closed again, this was indicated as the client having left the apartment. Nurses also said that some clients forgot to close the door when they left the apartment, which was not considered in the data analysis. These issues fuelled concerns over whether clients had actually been outside or whether the system was showing the wrong information, which was also evident in the diary notes.

Similarly, the system could not recognise whether there were several people within an apartment at the same time. This generated issues with the reported length and number of bathroom visits as well as activities in other rooms. In particular, practical nurses' 2–3 client visits every day and possible night patrol visits could cause incorrect measurements.

Therefore, nurses were sometimes confused about whether they could trust the information that the system provided or how the information should be interpreted. A nurse stated that 'It would be good to know if there has been an failure in the system, so that we could interpret the data correctly'. However, nurses also said that they would not completely rely on the measured data in making care decisions, as also reported previously (Klemets et al., 2017). Rather, as a nurse said, the system helps by 'providing a hint'.

## 5. Discussion

### 5.1. Adopting the use of an in-home monitoring system

Nurses were involved from the outset in the design of the proposed in-home monitoring system, and an initial prototype was deployed early on. However, user participation in the requirement elicitation process seemed insufficient for the system to be adopted in practice. The log data (Figure 3) revealed that nurses did not start to actively use the system before the second interview phase. System use exploded during the trial period but reduced afterward. Nonetheless, even if the number of logins reduced after the trial period, nurses continued to use the system regularly (2–3 logins per week).

Although nurses provided various reasons for the sparse initial use, the dramatic change in perception suggests that they did not appreciate the system's relative advantage before committing to trialling the system. Nurses' feedback indicates that some effort was required to learn how to use the system and interpret the graphs. Therefore, in Roger's terms, complexity (difficulty of understanding and using an innovation) can be considered one reason why the system was not adopted initially. However, through the system trial, nurses could learn to use the system; this reduced its perceived complexity and enabled nurses to perceive its benefits in their work.



Therefore, a key factor to adoption was how nurses ultimately perceived the system's relative advantage. The focus on clients with memory disorders and providing information about night-time activities was considered vital. As nurses otherwise lacked this type of information, the system provided an advantage in not having to solely rely on occasional observations or unfounded suspicions. In line with Glascock (2012), we argue that for in-home monitoring technology to fulfil its potential, it is essential to build customisable systems that meet actual information needs. Therefore it is important to identify who should be monitored, when, and for what purposes.

A common strategy in previous studies has been to equip older adults living in independent community housing with in-home monitoring technology that can detect early signs of illness using an 'one-size-fits-all' approach (Skubic et al., 2015; Alexander et al., 2011; Glascock and Kutzik, 2006). However, Reeder et al. (2013) noted that the vast majority of older adults live in traditional homes and that more focus should be directed toward supporting them. Grand visions often depict how future smart homes filled with various sensors and actuators will greatly benefit medical care (Muse et al., 2017); however, it is unlikely that such monitoring systems will be pervasively available in all older adults' homes within the foreseeable future. An alternative strategy could be to personalise the system toward an individual client or group of clients in close collaboration with carers to provide tailored information to support more precise care assessments.

For the clients involved in this study, the main question nurses seemed occupied with was 'Can the client live safely in his/her home?'. For older adults with dementia, finding the right answer to this question is a major challenge. In this respect, the in-home monitoring system was used not only as an alarm system but also as an information system queried by nurses to provide insights and clarity (Klemets et al., 2017).

This way of using the system also has implications for how it presents analysed data. Nurses were confused when the presented data did not meet their own expectations or experience (e.g. in case of incorrect measurements related to bathroom or outdoor visits). Such uncertainties can cause extra work and also negatively affect the perceived relative advantage of the system. Improving software algorithms to enhance machine validity is obviously one important aspect. However, as it is unlikely that the system will be able to classify all activities correctly at all times, making the analysis process more transparent to the user (Brown and Randell, 2004) could aid improving human validity. For example, if the nurse is made aware that the data analysis of an activity was based on an incomplete data set or that motion sensors were also triggered in several rooms, the nurse would be better equipped to make the correct interpretation that the analysis failed, whenever that is the case.

Hall et al. (2017) argued that staff training should also involve discussions on how to align monitoring technology with existing work practices and values to better understand the reason behind the technology use. Our results suggest that nurses' involvement in the technology implementation should

not only seek to motivate its use but also find out how the system could be used in a specific context. In other words, nurses should contribute to the design and configuration of both the technology and the associated practices through both trial periods and collaboration with system designers. In this respect, the evaluation probes functioned not only as a method to evaluate the in-home monitoring system but also as a tool that provoked nurses to experiment with and explore how the system could be integrated and used in their work.

## 5.2. Study limitations and open issues

Although the results are largely positive, a number of open issues remain. The low sample of nurses and older adults participating in the study was mainly due to the focus on technology design and development in the project. Initially, the aim is to build not only a monitoring system but also a smart home environment including different types of technologies for older adults. However, during the design process, it became evident as the project progressed that within the particular home care context, nurses needed a system to help them monitor clients with memory disorders. Future work should further investigate how the in-home monitoring technology could further be designed to meet this need in different home care contexts. A logical next step would be to scale the deployment to conduct large-scale studies on the effects of integrating system use into care practices.

The focus on a single case study can be considered both a strength and a limitation. The prolonged involvement period (three years) allowed us to gain a thorough and deep understanding of the context, work, and associated challenges. This strengthens the study's internal validity, which is further enhanced through the use of multiple data sources and observer triangulation (Robson, 2002). However, the external validity could still be improved through analytical generalisation, and it should be tested in other similar settings (Yin, 2003).

Further, privacy and ethical issues need to be carefully considered with regard to deploying in-home monitoring systems. Studies have reported that older adults are willing to trade some of their privacy for the ability to remain independent in their own homes and for gaining the enhanced sense of safety and security that these systems bring (Claes et al., 2015). Still, how security, privacy, and trust are managed in the proposed system is considered beyond the scope of this study.

## 6. Conclusion

By adopting a qualitative case study approach, this study investigates how an in-home monitoring system using PIR technology and designed with a user-centred approach is adopted into nurses' workflows. The findings suggest that the system can assist home care nurses in care assessment and decision-making. A key target group for the monitoring system is older adults with memory disorders living independently because it is challenging to assess whether this is feasible. The key factors in

425 system adoption were providing insights that alleviate these challenges and allowing nurses to trial the system. Further, nurses ability to influence the system design played an important role in integrating the technology as a part of nurses' work.

## 7. Authors contributions

Joakim Klemets contributed to the design, data collection, data analysis, and writing. Jukka  
430 Määttä contributed to the design, data collection, data analysis, and writing. Ismo Hakala contributed to the design, data analysis, and writing.

## 8. Conflict of interest

Declarations of interest: none.

## 9. Summary table

435 **What is already known on the topic?**

- Various in-home monitoring technologies have been proposed to support ageing in place.
- Previous studies suggest that such technology can have positive effects on the care of older adults.
- Few studies have investigated how such technology can be adopted to assist nurses in a home care context.

440 **What does the paper add?**

- An in-home monitoring system using passive-infrared sensors can support nurses in the home care of adults with memory disorders.
- Night-time activity monitoring provide nurses with important information that helps in care assessment and planning for older adults with memory disorders.
- 445 • Many factors influence the adoption and integration of an in-home monitoring system for home care into nurses' workflow.

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