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Research Article

Acceptability And Validation By Use Of A Location Device To Promote Resident Autonomy In Residential Facility For Dependent Elderly People.

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Abstract

This article presents an experimental study of a location-based system designed to enhance the safety of residents' ambulation within a nursing home. The primary objective is to assess the system's impact on resident support, its acceptability, and its potential to improve the well-being of teams and families. To achieve this, a multi-phase protocol combining technical and medical validation has been designed, including tailored training sessions for users. The approach also includes a comprehensive analysis of the outcomes, based on both qualitative and quantitative indicators. Initial findings suggest a notable improvement in residents' well- being and a substantial reduction in the daily burden of healthcare professionals.

Keywords : e-Health, Alzheimer patient, well-being, biomedical devices, biosensors, signal processing, locating device.

INTRODUCTION

Improving the quality of life and preserving the autonomy of elderly people living in residential facilities for dependent elderly people (RFDEP) are essential challenges in a context marked by accelerated demographic aging. This issue becomes even more complex when the residents have neurodegenerative pathologies such as Alzheimer's disease. Indeed, these conditions require constant vigilance to ensure the safety, while meeting specific needs that are often difficult to reconcile. These include uncontrolled wandering and the risk of running away which are primary concerns for staff and families. These frequently lead to significant restrictions to the movements authorized to residents, negatively affecting their autonomy and their psychological and physical well-being. Faced with this situation, the use of technological innovations, such as intelligent location systems have emerged as potential solutions and has been investigated.

Indoor Positioning Systems (IPS) now play a major role in ensuring safety and autonomy in contexts where GPS is unsuitable, as is the case in medical-social establishments [1, 2]. At algorithmic level, recent work [3, 4] show that recurrent neural network (RNN) such as LSTM (Long Short Term Memory) or GRU (Gated Recurrent Unit) offer improved accuracy for indoor tracking, significantly reducing localization errors. However, work in hospital environments [5, 6] demonstrate the strong dependence on human factors such as comfort of use ergonomics and the perception of safety by end-users. It is particularly true for nursing staff and patients themselves [7].

These devices offer a relevant response, combining enhanced safety with greater respect for residents' autonomy. They enable effective, yet discreet and non-intrusive surveillance, while preserving the freedom of movement and dignity of the people concerned. The experiment conducted at the Cité des Aînés in Saint-Étienne, France (CDASE), which is the subject of this article, is precisely in line with this approach. It is based on the use of Cartobat®, an indoor location-based system designed to track residents' movements and trigger relevant alerts for staff. The integration of innovative approaches is promising for research, such as

hospital digital twins [8], which enable modeling and dynamic prediction of patient journeys, as well as intelligent monitoring systems using IoT sensor networks.

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This article presents the results of the experiment and provides a detailed analysis of the factors influencing the adoption of such technologies in the healthcare environments, along with the operational recommendations to facilitate the respectful and effective integration of into the daily lives of RFDEP.

The rest of the article is structured as follows: Section “Materials and Methods” describes the technical, functional and experimental methodology. Section “Results and Discussion” present the results obtained, including ethical considerations, and analyzing the impact and limitations of this work. Finally, section “Conclusion” outlines prospects for improving and extending the system.

Paper contribution: This work contributes to the literature by providing concrete feedback on the integration of a monitoring system for elderly people in nursing homes. It offers a multidimensional analysis combining technical social acceptability and organizational impacts. In addition, it highlights the conditions necessary to promote the sustainable, widespread adoption of monitoring technologies in care environments.

MATERIALS AND METHODS

Monitoring system for seniors

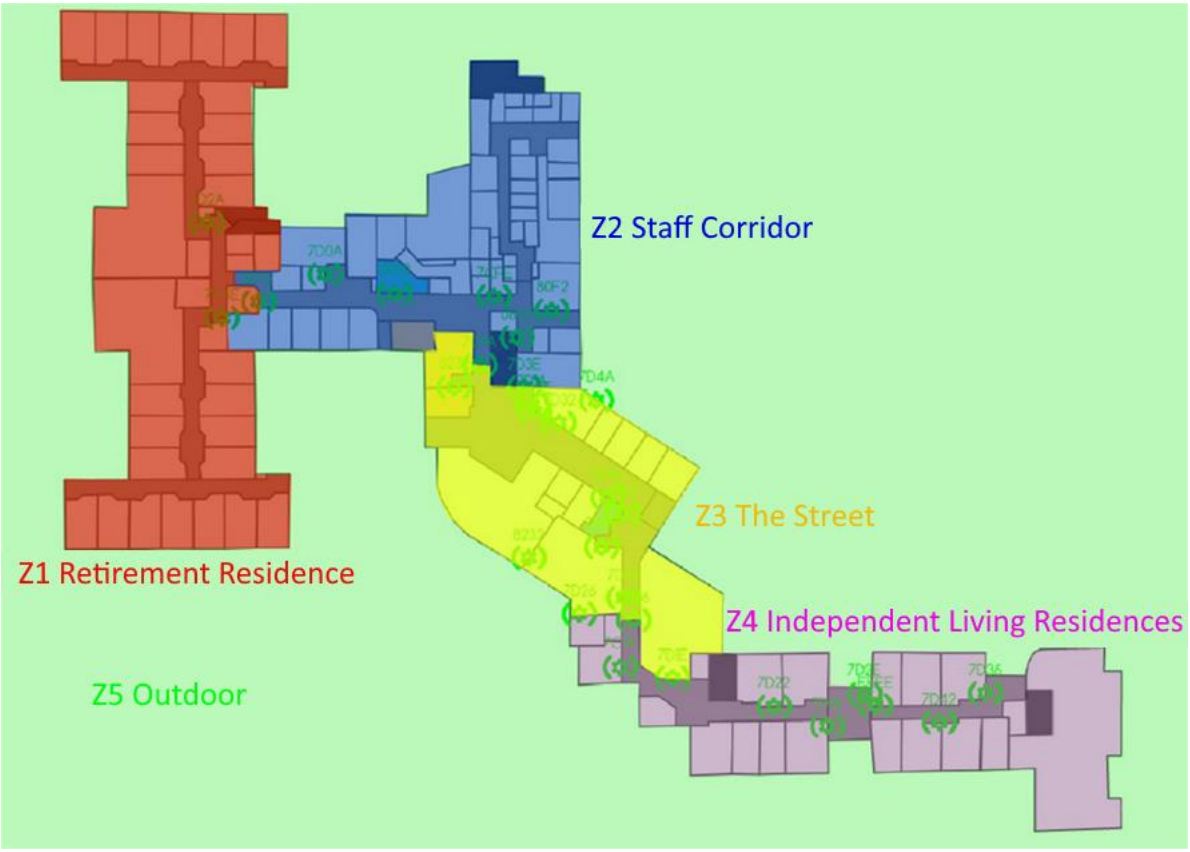
The Cartobat® system is an integrated solution for indoor tracking and orientation of individuals and equipments inside various type of building. It is part of a trend towards the use of IoT technologies in hospital and medical environments, such as Bluetooth beacons [5], ZigBee-based systems [6], and recurrent neural recurrent neural networks (RNN) [3, 4]. For its operation, the system consists of a CartoWear pendant (**Figure 1 left**), worn by each individual, and a several CartoModules sockets (**Figure 1 right**), which detect and transmit signals emitted by the CartoWears to the CartoCloud. In the current implementation, communication is established via WiFi. The CartoCloud, using remote servers, processes the radio signals and converts them into location data by taking into account the detailed cartography of the building.

Figure 1. Example of installation of a CartoModule and a wearable CartoWear



The installation follows a predefined map and the CartoModules are strategically positioned to generate real-time alerts whenever a resident exits a designated area. The current cartography has been specifically designed to identify secure areas (see Figure 3), enabling residents to move around freely in a controlled environment during the experimental of the Protected Living Units (UVP). In the illustration provided in **Figure 2**, any crossing of one of the four defined zones (Z1 to Z4) is signaled by the activation of a flashing green dot on the caregiver’s mobile terminal, indicating the resident’s exit within less than one second.

Figure 2. Safe walking zones (Z1, Z2, Z3 and Z4) when UVP residents are discharged.



Experimental schedule

The experimentation of the system as part of the project (called LISE) took place in several successive phases, in order to evaluate its effectiveness, acceptability and organizational impact. The project was carried out according to a timetable structured in several phases.

Phase 1: preparation initiated in June 2021, enabled us to define the scope of the project, identify the criteria for and to structure the follow-up protocols. Then, between September and November 2023 (phase 2), the system was deployed with the installation of CartoModules and CartoWears. From January to June 2024 (phase 3), the experimentation was progressively implemented on site, enabling the monitoring of residents and the collection of the behavioral and medical data. Finally, between July and August 2024 (phase 4), the results were evaluated through an in-depth analysis of the data collected, feedback from stakeholders and adjustments for future implementations. To ensure the smooth running of the protocol, regular follow-up meetings were organized with all the players involved, from the beginning of phase 1 to the end of phase 4. The nursing staff, including nurses, orderlies and psychologists, contributed to the implementation and to the monitoring of residents' progress. The coordinating doctors validated the medical prescriptions and the impact of the system on participants' health. Engineers and researchers analyzed the technical performance of the location and alarm system and proposed adjustments where necessary. Families and caregivers were approached to gather their feedback and promote the devices of the system. During phase 3, each meeting between nursing staff provided an opportunity to review the outings the logistical aspects involved, and to assess and evaluate residents' reactions, in order to adjust protocols accordingly. A dedicated time was given to all staff involved in the participating in the experiments. This included a presentation of the project's objectives and experimental framework, as well as an introduction to the specifics of the Cartobat® system and the data collected. Participants were also trained in how to accompany residents in different types of outings and were reminded of the ethical principles and data protection measures. This initiative ensured consistent implementation of the protocol and optimized interaction between the various stakeholders.

Methodology followed

Among the 28 residents of the two UVPs, 4 met the inclusion criteria and participated in the experiments after validation by the coordinating doctor. **Table 1** summarizes the characteristics of the four residents who took part in this study. The four residents

have the same GIR-value. The GIR is a classification system used to determine the level of dependency of an elderly person. This index is based on a standardized assessment carried out using the AGGIR grid (Autonomie Gérontologie Groupes Iso-Ressources). The grid measures a person's ability to perform essential activities of daily living. GIR levels range on a scale from 1 to 6; GIR 1 represents individuals who are completely dependent and require constant assistance, while GIR 6 designates those who are autonomous in their daily activities.

Table 1. Study participants

Label	Age	Sex	Arrival Date	GIR
R1	92	F	March 2021	2
R2	93	F	February 2021	2
R3	92	M	December 2022	2
R4	82	F	February 2022	2

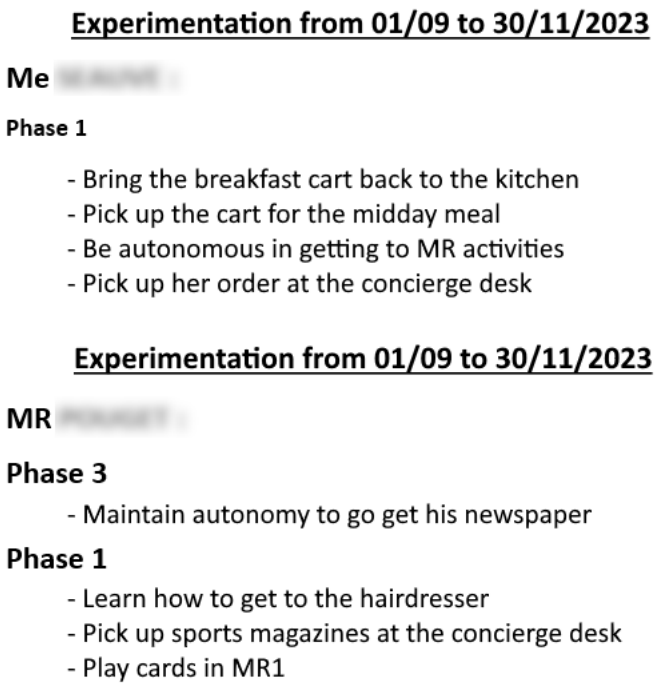
Calculating the GIR is crucial for guiding support and assistance measures. GIR2-value designate people who are also highly dependent, but retain partial participation in certain activities with assistance. This level includes people who are bedridden or who have significant impairment of their mental capacities. The 15-minute outings were carried out under medical prescription. Each outing is associated with a precise objective, in line with their own personalized project. These objectives include picking up a newspaper, going to the hairdresser's shop, bringing coffee at the brasserie, or return the breakfast cart and pick it up the for lunch.

Each resident can be in one of three phases defined (below). The study participants were assigned to a phase every two weeks by the nursing staff according to individual progress.

Phase 1: The resident is accompanied.
Phase 2: The resident leaves under constant remote visual supervision.
Phase 3: The resident is autonomous and carries out without direct supervision.

In order to ensure individualized follow-up, each resident is provided with a scenario sheet, enabling to analyze his or her discharge objectives and progress through the various phases (see **Figure 3**). A total of 87 outings in the building and garden were recorded: 6 outings for R1, 3 for R2, 30 for R3 and 48 for R4. In order to assess the evolution of the residents' condition, a total of 12 psychological assessments were carried out using the NeuroPsychiatric Inventory (NPI). Each resident was assessed three times: at the start of the experiment, midway through and at the end. The NeuroPsychiatric Inventory (NPI) is an assessment tool used in mental health to analyze neuropsychiatric symptoms, particularly for patients with dementia, such as Alzheimer's disease. It enables to evaluate a broad spectrum of disorders, including depression, anxiety, hallucinations, agitation and sleep disorders. The assessment is based on a structured interview with the caregiver, collecting data on the frequency, severity and impact of symptoms.

Figure 3. Example of a scenario follow-up sheet for two residents.



Experimentation from 01/09 to 30/11/2023

Me [redacted]

Phase 1

- Bring the breakfast cart back to the kitchen
- Pick up the cart for the midday meal
- Be autonomous in getting to MR activities
- Pick up her order at the concierge desk

Experimentation from 01/09 to 30/11/2023

MR [redacted]

Phase 3

- Maintain autonomy to go get his newspaper

Phase 1

- Learn how to get to the hairdresser
- Pick up sports magazines at the concierge desk
- Play cards in MR1

The NPI provides both a quantitative analysis, via a numerical score and a qualitative analysis of disorders. It is used for diagnostic purposes and to monitor the evolution of symptoms in order to assess the effectiveness of interventions. Although primarily intended for dementia patients, it can also be applied to other neurological and psychiatric disorders. The total score of the NPI can reach 144 points, reflecting the severity and frequency of the patient's neuropsychiatric disorders such as anxiety, depression, hallucinations and behavioral changes. An additional scale of up to 60 points allows assessing the impact of symptoms on the care team. This measure aims to quantify the burden placed on healthcare professionals and, if necessary, to adjust support strategies to ensure the well-being of both patients and staff.

Residents, families and staff were involved from the outset through meetings and a co- creation process. A Design session was used to assess the possibility of opening the UVPs with a location and alert system that reconciles autonomy and security. Prior to deployment of the system, a structured information and consent gathering was obtained from families to ensure their full support for the project. Regular exchanges enabled the system to be gradually adapted to the expectations and feedback of the various players involved. Some caregivers even took an active part in the process, going so far as to install part of the system themselves, demonstrating their strong commitment to this technological innovation. In addition, the importance of the device's design proved to be a decisive factor in its acceptance by end- users. This collaborative dynamic strengthened the transparency of the project, facilitated the integration of the solution within the facility, and significantly improved interactions with families, contributing directly to the success of the experiment. This multi-dimensional approach, taking into the specific expectations and constraints of each stakeholder, was a key factor in confirming the acceptability and operational effectiveness of the system.

RESULTS AND DISCUSSION

As mentioned in the previous section, residents R3 and R4 had the highest number of outings. For residents with cognitive illnesses such as Alzheimer's disease, maintaining a daily ritual is an essential factor in providing a sense of security and comfort. This protocol is primarily aimed for residents suffering from early-stage neurodegenerative diseases, offering supervised outings intended to reduce isolation and enhance emotional well-being. However, as the disease progresses, accompanied by increasing impairment of cognitive and perceptive abilities, these outings gradually lose their therapeutic value. Indeed, when the resident is no longer able to perceive their environment clearly or to situate themselves spatially, it becomes necessary to find other forms of support, better adapted to their condition. Ongoing assessments of residual cognitive abilities are essential to adapt activities to the evolving needs of each individual, ensuring that care remains progressive, personalized, and appropriate. Resident evaluations are presented in **Tables 2 and 3**. The results show contrasting effects on residents' behavioral for R1, although the reduction in symptoms was modest but a significant decrease in caregiver burden suggests organizational benefits, particularly in reducing anxiety-related requests. R2 exhibited a clear behavioral improvement, though the impact on caregivers remained limited, given his initially low burden score. In contrast, R3 showed substantial improvement, with a marked reduction in anxiety due to supervised outings. This contributed to greater behavioral stability and reduced the need for assistance.

Table 2. NPI assessment results: neuropsychiatric score

	NeuroPsychiatric Score /144		
Label	**Start**	**End**	**Diff**
R1	26	24	-2
R2	15	9	-6
R3	32	21	-11
R4	15	23	+8

Table 3. NPI assessment results: score impact

	Score Impact /60		
Label	**Start**	**End**	**Diff**
R1	10	3	-7
R2	6	4	-2
R3	7	5	-2
R4	5	5	0

Conversely, R4's troubles intensified, as a result of a disruptive event linked to the transfer of a friend with a high level of dependency. With the support of a psychologist, she adjusted her discharge objectives to preserve her well-being. Ongoing, individualized assessment is essential to adapt care to the changing needs changes. The flexibility of the protocol enables us to optimize interventions by considering the behavioral and emotional dynamics of each individual.

The ritual associated with wearing the pendant also proved psychologically reassuring. One resident refused to go out because of the absence of the pendant. This perception contributes to a form of psychological security, where residents feel free to go out with the certainty of not being forgotten. The results obtained led to an in-depth analysis within the multidisciplinary team, leading to in-depth reflection on the aspects of the protocol. From now on as early as the pre-admission visit (VPA), a resident's eligibility for the scheme is systematically assessed to anticipate the match between their particular needs and the benefits. The nursing

staff, in direct daily contact with residents, play a decisive role in proactively identifying candidates likely to benefit from the scheme. This increased involvement is testimony to the successful integration of the protocol into standard care practices, taking full account of operational realities in the field.

In addition, the experiment also revealed strong engagement from family caregivers, who expressed increasing interest in the program's benefits. Several families volunteered to equip their loved ones directly with the tracking pendant, demonstrating their active support for the project. This commitment clearly demonstrates families' recognition of the benefits of this technology in terms of safety and improved well-being. Finally, the importance of the device's ergonomics design was emphasized by caregivers, with some suggesting improvements to the pendant's form factor. his feedback illustrates that comfort and usability are critical factors for successful adoption of new technologies in medical-social settings. Overall, these developments reflect a positive evolution in care practices, where technological innovation is paired with stronger collaboration between professionals and families to promote more inclusive, participatory approaches.

Factors influencing acceptability and appropriation

A dedicated trial aimed at evaluating the acceptability of the system among residents, families and care teams identified several key factors influencing its adoption in a medical-social context. Generally speaking, residents responded positively to the device, whether in the form of a pendant or bracelet. Most did not report any discomfort with daily use and some residents even quickly integrated the device into their routines, perceiving it as a source of reassurance. However, notable differences emerged among residents with more advanced cognitive impairment, for whom appropriation of the device proved to be more delicate, requiring greater attention. For healthcare professionals, the system was generally perceived as a facilitating tool, enhancing safety without unduly restricting residents' autonomy. However, the trial revealed that managing notifications sometimes introduced additional cognitive workload for caregivers, mainly due to an excessive number of alerts to too many irrelevant alerts. This highlights the need to fine-tune alert thresholds to ensure optimal use of the device of the system, avoiding an information overload that could undermine its operational effectiveness.

Furthermore, the active involvement of the families was fundamental to the protocol's success. Information and awareness sessions helped establish trust and foster confidence in the system, despite some reservations regarding aesthetics and comfort of use (pendant or bracelet). These concerns are a reminder of the central importance of design and ergonomics in facilitating the integration of new technologies into the daily lives of the elderly. So, by combining transparency, education and consideration of practical and aesthetic aspects, this collaborative approach encouraged greater acceptance and strengthened the overall acceptability of the system within the community. The fact that the objectives were in line with those of each resident's personalized project residents, their families and care staff, was also a key issue

Ethical issues

One of the major challenges of the project was to reconcile the safety of residents with respect for their individual freedoms. Although the system aims to limit excessive confinement in UVPs, its operation based on the location of residents can be perceived as a form of intrusive surveillance. This concern was frequently raised during stakeholder discussion. The acceptability of the device varied according to the individual: some residents perceived the device as a reassuring factor, allowing them to go out while being protected; and others showed an initial reluctance, fearing excessive control of their movements. To address these concerns, clear procedures for informed consent and ongoing communication were implemented, forming a cornerstone of the project's ethical framework. As required, consent from legal representatives was obtained before residents were included in the study.

Limitations

The implementation of the tracking system revealed significant resistance to change among caregivers, residents, and families. Variation in observer training affected the consistency and quality of experimental observations, complicating the interpretation of results. Some residents expressed reluctance, notably due to the design and appearance of the pendant, while families voiced concerns that required additional efforts in communication and reassurance.

The experiment also revealed certain methodological limitations. The small number of outings analyzed limits the generalizability of the results, and the effect of the observers' presence may have biased the evaluation of the device's acceptability. A larger-scale clinical study, involving more participants and conducted over an extended period, is recommended to refine the analysis of its impact. Despite these challenges, the LISE project has demonstrated the potential of the device to improve residents' autonomy while guaranteeing their safety.

However, adjustments remain necessary, in particular to reinforce the device's reliability, However, further adjustments are needed, particularly to enhance system reliability, refine alert thresholds, and raise awareness among stakeholders to foster ethical and sustainable adoption. Continued development and optimization of the tracking solution may ultimately enable the establishment of an effective and

respectful technological support model for dependent elderly residents in care facilities. This work is currently ongoing.

CONCLUSION

The trial confirmed the potential of the Cartobat® system to enhance the autonomy of residents while ensuring their safety. Nevertheless, several avenues must still be explored to assess its long-term effectiveness. With this in mind, validating the impact of the system over extended periods is necessary. In this regard, validating the system's impact over extended periods is essential. Likewise, the progressive deployment of the system in other care facilities and in home care settings represents a promising direction, enabling an evaluation of its adaptability to different operational contexts.
In addition, the integration of artificial intelligence-based tools offers exciting prospects. For example the use of predictive techniques could enable effective anticipation of risky behavior as well as a dynamic adaptation of risk management thresholds based on changes in residents' behavior. This technological lever would encourage more individualized care, by proactively adapting safety measures, while preserving the autonomy of the people concerned and optimizing caregivers' interventions. Last but not least it remains essential to further explore the possibilities offered by this technological approach, particularly through in-depth studies of the cognitive, behavioral and organizational impacts. Future research should enable rigorous and extensive validation of medium- and long-term benefits facilitating precise quantification of the results obtained. Dynamic and predictive identification of at-risk journeys using algorithms appears to be a promising avenue for refining warning thresholds and further improve operational efficiency of the system.

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