Innovative Technology-Based Healthcare and Support Services for Older Adults: How and Why Industrial Initiatives Convert to the Living Lab Approach

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Abstract. To support older adults with age-related or chronic diseases living in the community, suppliers are increasingly turning to Personal Health Systems (PHS) for remote care delivery. Despite the advantages of PHS, implementing these systems brings on several challenges on the technical level, but also related to the diversity of end-users, the characteristics of the ecosystem, the innovation process itself, regulatory and social aspects. To discuss these issues, we study two different PHS currently under implementation and deployment by two French companies: a telehealth service for frail older adults living at home and a GPS-based monitoring service to deal with wandering and disorientation of persons with dementia. We describe and compare problematic situations faced by these companies on three levels - demand, supply, and context- and explain why they decided to evolve towards a Living Lab approach to improve technology acceptance and social and economic return on investment.

Keywords: Living-lab · Innovation · Healthcare · PHS · User involvement · Older adults

1 Introduction

Healthcare systems in Europe currently face many challenges due, in part, to the general background of the economic crisis resulting in limited public expenditure, budget cuts, and fiscal austerity [1]. Population ageing is another key factor putting a strain on healthcare systems, particularly in a context of healthcare providers shortage.

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Therefore, dealing with questions such as how to achieve and maintain a good health status throughout the life cycle, and how to deal with common chronic diseases and disabilities in old age, seems fundamental [2].

An individual's health status results from the interaction between genetic and environmental factors [3]. Understanding these interactions, and the extent to which they contribute to the risk of illness, is important for the development of preventive and therapeutic measures supporting a healthy, active and independent life throughout an individual's existence. Innovative approaches for reaching better health outcomes at the population level may seek to improve the identification of risk factors, prevention strategies, diagnostic procedures, and enhance care quality and efficiency. Health policies are critical for the implementation of these innovative approaches because they guide initiatives and contribute to shape services and resources. In this context, the use of Information and communications technologies (ICTs) for health promotion and disease prevention has been growing rapidly in recent years, mainly in high-income countries [4].

The use of ICT in the healthcare context is expected to improve cost-effectiveness, safety, quality, availability and continuity of care delivery. Therefore, to better support elderly populations, commonly affected by age-related or chronic diseases, service suppliers are increasingly turning to remote care delivery systems, of which Personal Health Systems (PHS) are a major component. PHS refer to a number of ICT-based tools, such as wearable, implantable, and portable systems, that automatically acquire, monitor and analyze health-related data in a continuous and unobtrusive way. Health data is then coupled with expert biomedical or psychosocial knowledge for the prevention or treatment of a condition. PHS also take into account individual and environmental information to offer the most appropriate response to the user. Responses can range from the delivery of information (e.g., personalized nutrition advice) to remote or personal assistance (e.g., call centers, point-of-care systems) [5].

Within the eHealth area, PHS focus on providing individualized and quality-controlled services that empower individuals to have an active role in their own healthcare regardless of their location [6]. Consequently, PHS are expected to improve quality of care, process efficiency and care delivery costs, either in public or private settings. Finally, it is worth noting that from an industrial point of view, PHS provide new business opportunities in Europe and globally, with a potential to bring a significant return on investment (ROI) and generate savings in resources [7].

PHS are diverse (e.g., telehealth, health information exchange, communication, mobile and assistive technologies, etc.) and cover different situations (e.g., emergency, prevention, regular therapy, home monitoring, nutrition support, etc.). Due to their wide range of applications, PHS appear particularly interesting for delivering home care and related services to older adults who want to continue living at home for as long as possible. However, their design and implementation brings on several challenges, of course on the technical level, but also related to the diversity of needs, capabilities, preferences and goals of end-users, to the characteristics of the social and physical environment in which they live, or to the features of the local ecosystem (e.g., organizational complexities, political aspects, regulatory restrictions or insufficiencies).

In this paper we provide a general analysis on the industrial processes for the development and implementation of PHS that specifically target older adults with

particular health and social care needs. First we provide some background information and summarize a number of challenges that healthcare technology companies may encounter when developing PHS. Then we introduce two PHS developed by French companies that are either under current development or already deployed. The first one is a telehealth service for frail older adults living at home. The second is a Global Positioning System (GPS) to deal with wandering and disorientation of persons with dementia. For each example we describe challenging situations encountered by these companies at different stages of the product development life cycle. We also explain how these challenges could be more successfully addressed by the implementation of Living Lab principles of open innovation, real-life experimentation, user involvement, and stakeholder partnerships. Finally, we build on these case studies to provide an analysis on how stakeholders in this industry sector may take advantage of Living Lab methods at different points of the product cycle.

1.1 Challenges Faced in the Development of PHS

Challenges faced by healthcare technology companies when developing PHS for elderly individuals can be grouped into three categories described in this section.

From the Demand Side: Tailoring Systems to Users. PHS users are very diverse including older adults, family members, informal or formal caregivers, among others. Because a wide range of persons may interact with PHS, these systems should be adaptable to various needs, capacities, limitations, preferences, and goals.

Several factors that may directly or indirectly hinder acceptance and adoption of PHS among older adults have been documented in the literature: (a) having a limited technology experience [8, 9]; (b) age-related changes in visual, auditory, motor and cognitive function, that render difficult the use of technological products [10–12]; (c) slowness in technology adoption compared to younger adults [13]; (d) being very selective in the choice of technologies they use (e.g., more frequent use of health care devices than entertainment technologies) [9]; (e) psychological aspects such as low self-confidence when using technological products, or having a negative perception of these products (e.g., being unnecessary) [13–15]; (f) assistive technology products conveying a negative connotation or appearing stigmatizing (e.g., highlighting disability) [16]; (g) ethical concerns regarding the use of PHS (e.g., mistrust, respect of privacy, dignity, autonomy) especially when the primary user has cognitive impairment; and (h) the high heterogeneity observed among elderly individuals (e.g., geographic, demographic, psychographic, and behavioral characteristics) which makes it difficult to draw a good picture of consumer segments [17].

All these factors represent a serious challenge for the development and implementation of PHS for older adults. Therefore, these systems must be designed with a strong concern of customization regarding elderly individuals and stakeholders around them. Consequently, participative and user-centered methodologies appear to be the most promising design approaches to address these issues.

From the Supply Side: Promoting a Collaborative Market Orientation. In order to keep up to date with globalization, technological change, and the rapid shift in industry

boundaries, a new model for market orientation has emerged over the past years: the "open innovation" model. Contrary to classic hierarchical models of "closed innovation" in which one organization controls entirely the R&D process, owning the intellectual property of the production, the "open innovation" model refers to cooperation among multiple stakeholders who share their perspectives to foster innovation (e.g., cross-product, cross-firm and cross-industry business models) [18, 19]. The rationale behind this approach is that, when developing new products, the choice of involving multiple stakeholders, and combining their knowledge, methods, and technology, can bring an added value to the product.

Cooperation for the development of PHS within an open-innovation model implies including several firms in the sector, healthcare providers, suppliers, researchers, and end-users, among others. These partnerships may involve public, private and civic sectors of society. However, different risks associated to open innovation activities have been identified, for instance: loss of knowledge, high coordination costs, loss of control, high complexity, and conflicting interests. Some barriers to open innovation activities have been highlighted as well, such as the difficulty establishing effective partnerships, the unbalance between open innovation activities and daily business, insufficient time and financial resources, and intellectual property issues [20].

The higher created value for all stakeholders that can be achieved by properly conducted open innovation, when compared to traditional approaches, justifies the creation of specialized, independent organizations to deal with these issues. By employing solid and structured methodologies, it is indeed possible to collect and organize knowledge to prevent its loss, balance interests objectively to resolve conflicts, coordinate efforts to reduce costs, and mitigate negative interferences of the innovation process with the core activities of partners.

The Context: Legal, Social and Policy Issues in Innovation. Legal, social and policy issues may arise at different stages of the innovation process, from the design of PHS to their implementation in home or institutional settings. These questions do not only concern decision-makers, legislators, and policy-makers (e.g., adapting existing laws to new healthcare practices) but also users (e.g., patients, families, caregivers, health professionals) and manufacturers [21]. From a broad perspective, stipulations at this level may support or hinder industrial processes, research, and the diffusion of proven technologies.

A widely acknowledged legal challenge to the implementation of PHS systems is the respect of patient's rights regarding privacy and data protection. In the European context, it is worth reminding that there is a move towards greater integration. Therefore, cross-border collaborations for technology development and implementation, patient mobility, and the sharing of health records that results from it, require all the reflection on legal aspects for the development of PHS at the region level. However, up to now there is a lack of a unified body of legislation for eHealth in Europe [21].

With respect to social aspects, one key issue regarding the adoption of PHS is the degree of ICT readiness of potential users. A recent European [22] study pointed out that new health inequalities are emerging due to the impact of "traditional determinants of health" on ICT readiness. Therefore, e-Inclusion policies related to "ICT for Health" are needed to ensure that individuals with low socio-economic status, low technology

experience, and more prone to health problems, are able to benefit from these types of technologies, in particular regarding elderly persons.

Here too, independent organizations able to federate all stakeholders, balance their interests through objective measures and synthesize these data to inform policy makers are needed. These organizations could particularly help to speed-up the necessary evolution of the legal and regulatory context, which today is slowed down by conflicting interests at the highest levels and the lack of a proper space for their resolution.

2 Two French Case Studies of PHS

In this section we give more concrete examples of the aforementioned challenges based on two case studies about the development and implementation of PHS. These studies cover different stages of the design and development cycle, and were chosen because they illustrate well the problematic situations faced by companies in the PHS sector.

2.1 SESIN and the Hadagio Telehealth System

SESIN is a French content management software publisher created in 1976. It has recently expanded its activities to e-health. The company is based in Marseille but is present in other French regions, in some African countries and in Brazil. Within the framework of a French Ministry of Health call for promoting health and independent living through ICT, the company conceived the project "Hadagio" in 2012.

Hadagio is a PHS intended to provide medical and social services such as tele-consultation, remote monitoring, social digital space, to frail elderly living in the community. The detection of unusual biological or behavioral patterns can automatically trigger an alarm notifying an informal caregiver or other care provider. The main goal of Hadagio is to improve health outcomes in older adults by supporting self-care and coordinated care. Overall, support services provided by the system are expected to prevent worsening of frailty and some of its adverse outcomes. The solution may be installed on tablets or smartphones and is expected to be used by patients, family members, and care providers. With the aim of ensuring acceptance and usability of the system, the company decided to give a particular attention to ergonomics throughout the design process of the system. A classical user-centered approach, structured into five phases, was used for the conception of the system (Fig. 1).

Although user-centered design methods were used to facilitate the appropriation of the system by users, and a satisfactory usability of interfaces was achieved, several barriers to acceptance still emerged. For instance, in Phase II-b (Fig. 1), an informative booklet was designed to ease the recruitment of participants for the pilot assessment (Phase V). The booklet introduced the system and presented a number of fictional scenarios illustrating how Hadagio could be used to support health and social care in elderly individuals. Results from the Phase I, and supporting literature on this topic, were used for this purpose. However, when gathering the opinions of older adults on

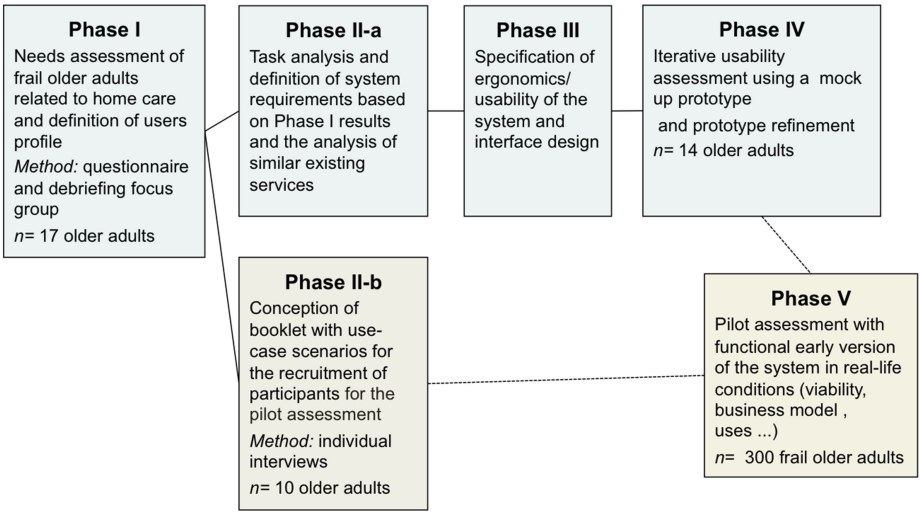

Fig. 1. Phases of design and evaluation of the Hadagio system

the information presented in the booklet, the project team noticed a low acceptance of the system. Participants' concerns pertained to different aspects:

- Technical feasibility: *"Remote health monitoring using sensors is fine, but how does one process data from sensors for all the patients? It's a huge job!"*
- Reliability: *"How do we prevent accidental triggering of alarms? We don't want emergency workers to come for nothing."*
- Intrusiveness: *"What type of sensor does the system use? Cameras? I do not want cameras at my home!"*
- Practical aspects: *"For tele-consultation, how does it work for payment, orders…? We must be there for that!"*
- Mobility: *"How does it work when we go on vacation? We must take our sensors with us?"*

Participants' feedback showed that the situations presented in the booklet appeared to be, first, far from their reality, and second, created a conflicting perspective with the way they wish to live at home and take care of their health. Older adults failed to perceive the usefulness of the system, which prevented them to imagine themselves as future users. The company acknowledged that because of its innovative character, implementing a system such as Hadagio would require a change of current self-care practices that could not be predicted neither promoted without the involvement of potential users. It was then decided to work more closely with older adults for the conception of more realistic use-case scenarios that would influence in a positive way the intention of use. This means giving them a more active and expert role and recognizing their right to decide over things affecting them.

2.2 Bluelinea and the BlueGard GPS Location Bracelet

Bluelinea is a French company working in the sector of PHS and connected objects since 2006. Based in the Paris region the company is nowadays present in several regions of the country. Since its beginnings, Bluelinea quickly evolved to position itself as a leading actor of the deployment of connected objects within health facilities. One of the first products marketed by the company was a monitoring bracelet for the protection of newborns in maternity hospitals. Building on the success of this offer, the company expanded its activity in 2010 to the support of older people. The monitoring bracelet "BlueGard" was then adapted to be used by people with dementia at risk of wandering and disorientation and support their caregivers.

The BlueGard bracelet (Fig. 2) is equipped with a GPS chip. It transmits its position to a support platform, and allows communicating with the user in case of need. It also includes an emergency button that the user has the option to use at any time. This solution falls under the category of PHS because it allows customization in terms of the definition of the location perimeter following the user's capacities, preferences, goals, and living situation.

Fig. 2. The "BlueGard" bracelet for monitoring the location of persons with dementia

The main purpose of BlueGard was to support older adults with dementia living in the community and help them continue living at home, with safety and independence, for as long as possible. The service was also intended to give respite and alleviate the stress of family members and informal caregivers of persons with dementia. A secondary use anticipated for this system was to provide healthcare institutions for older adults (e.g., retirement homes, geriatric hospitals) with a support service to prevent elopement and improve resident's safety.

However, the offer did not reach the deployment level originally anticipated by the company. Nowadays approximately 1000 units are distributed each year, with a mean number of 300 active users at a given time and around 50 to 60 alarms triggered each day. Contrary to expectations, 70 % of users are in healthcare institutions, with only 30 % living at home. Several reasons can explain this situation:

- *Social environment characteristics*: absolute need of a caregiver at home to recharge the bracelet, informal caregiver being too old, or not having the possibility

to pick up the person with dementia after he or she was located following an elopement episode (e.g., not having a car).
- *Technology-related*: size of the bracelet, negative design (e.g., stigmatizing), reduced autonomy (e.g., need to be charged at least 3 h everyday).
- *Service introduced too late*: the offer does not appear to be effective at later stages of dementia. The company has observed that families frequently look for a support solution after experiencing one or several elopement episodes, when usually other responses would be needed (e.g., institutionalization).
- *Ethical and regulatory aspects*: Some particular and institutional clients worried about the idea of infringing the autonomy and privacy of the person with dementia.
- *Costs*: No clear model of financial support for families taking care of a person with dementia, requiring changes at the policy level.

Yet, by being very attentive to users' and market feedback "after-the-fact" even though no proper co-creation approach was used in the beginning, the service could also be refined throughout the years. For example, improving the definition of the monitoring and location area according to each individual's needs. Also, a partnership with local cab companies was established, to help caregivers who did not have the possibility to pick up the person with dementia in case of elopement. The company has also gradually developed and applied an ethics charter defining high-level principles for the provision of remote monitoring in dementia. Nevertheless, the organization acknowledged that the lack of a structured approach to use data collection and analysis hindered the identification and implementation of critical modifications that would have helped to reach higher market penetration.

3 The Living Lab Approach as a Solution

The Living Lab approach is a recent but potentially influential stream in the field of innovation research that is structured around five basic principles [23]:

- *Openness:* The conception and evaluation process of a product or service should be public and anyone who considers him/herself potentially impacted can get involved in the operation.
- *Influence:* All parties involved must have a balanced influence on the final result, meaning that no stakeholder should be able to stir the project according only to his/her own goals.
- *Reality:* The conception and evaluation of the solutions should be based on quantitative and qualitative evidence collected as ecologically as possible. This means involving actual users, focusing on actual issues and testing solutions in real-life using the organizational and logistic setup projected for the final solution.
- *Value creation:* The conception and evaluation process should create value for everyone involved. Thus, the focus should not be only on economic value, but also on the social impact of the solution.
- *Sustainability:* Conception and evaluation should be an integral part of the project throughout its entire lifespan, meaning that the proposed solution should evolve and be re-evaluated thanks to feedback from the field. This makes it necessary to have

sustainable conception and evaluation processes, able to be self-funded through a re-investment of part of the value created.

With respect to the PHS examples here presented, while neither firm has truly applied a complete Living Lab approach, both have taken steps to operate according to some of its core principles. In this section we explain how a full implementation of Living Lab methodologies, at different moments of the product cycle (e.g., development and deployment), may positively impact the innovation process in both companies.

3.1 SESIN and the Hadagio Telehealth System

To allow potential users better imagine the conditions for a future use of Hadagio, SESIN intends to engage users in a process of *creative mediation* [24]. This method proclaims that making potential users participate in the writing of usage scenarios for innovative technologies helps them having a more clear representation of their usefulness and start shaping an intention to use them [24]. In this method, first, some services of the system are selected. Then, draft scenarios are presented to potential users, with "problematic" and "adjustment" situations without including the system. Participants are asked to complete these draft scenarios by imagining they play the main role in them. This practice may help participants identify and define unmet needs that could be potentially met by a product or service. In a second time, the system is included in the storyboard. Participants are then invited to imagine potential problems when using the system and possible solutions. Based on these elements, more realistic scenarios can be co-designed having constraints and solutions articulated in a coherent story.

This technique should provide a concrete framework to help prospective users to build a personalized scenario that fits well with their needs, goals, and preferences. For SESIN such a method is expected to be more effective for identifying determinants of technology acceptance than a questionnaire survey. For its implementation, a Living Lab approach appears as a particularly appropriate response because it offers a set of tools, methods and infrastructures [25] that effectively support participatory research for the construction of product usage scenarios. For this reason SESIN has decided at this point of the design cycle to move to Living Lab methodologies.

3.2 Bluelinea and the BlueGard GPS Location Bracelet

As part of Bluelinea further development of the BlueGard bracelet, the Living Lab approach, to which the company has recently turned, is expected to prove very useful. First, at the user level, the participatory approach recommended by the Living Lab can help improve product acceptability in terms of improved product appearance (e.g., more positive design), specifications of the system (e.g., improving their autonomy to reduce the need to recharge frequently), and training needs, as part of a co-design work. Openness and user involvement may also help the company to anticipate other

potential partners, instead of discovering them afterwards, as it was the case with partnership with the cab company.

The Living Lab can also contribute to the improvement of the BlueGard service by putting in place a systematic approach to quality-controlled usage data collection and analysis. This is expected to help the company better demonstrate the profits of supply and better position itself in the market by better informing and assuring decision-makers (e.g., managers of healthcare organizations, caregivers) with respect to legal risks, and their tradeoffs with respect to safety/risks, benefits and costs.

It is worth noting that GPS systems for monitoring the location of persons with dementia seem to be better positioned in other countries than France by local dementia associations. For Bluelinea, the Living Lab approach can also help at the regulatory level to improve awareness of existing technology-based solutions regarding wandering and disorientation problems of persons with dementia. In order to demonstrate cost-effectiveness of the offer, necessary to be supported by local health authorities, Living Lab methodologies are also expected to contribute to the ROI study, the analysis of data related to users' enrollment, technology and operating costs, personnel or staffing costs. This strategic choice was made by the company to overcome an "opportunistic" approach and be in line with healthcare policies regarding the implementation of evidence-based practices.

4 Conclusion

In this paper, we have explained how two French firms developed very different PHS using approaches that were partly in accordance with Living Lab principles but did not fully implement this kind of approach. While original strategies used by both companies did address some challenges in interesting ways, and truly moved to personalization, which is rarely the case, technology acceptance and market take-up has remained low for both.

We have explained why we think that a more rigorous Living Lab approach would have produced better results, and how future versions of these two PHS will benefit from such a move. With these two examples, we have illustrated how innovative companies can benefit from this approach throughout the entire innovation process: concepts should be tested with both users and experts to generate feedback; mock-ups should be reviewed by users in realistic contexts to help generate useful, adequate scenarios; early prototypes should be tested in model environments and then in the real-world to iterate over the design, specifications and accompanying service; more mature solutions should be deployed in the real world as soon as possible with systematic logging and analysis of generated data and user feedback for gradual improvement; and finally companies and Living Labs should join forces to push authorities to improve regulatory and policy context by providing real-world, scientific evidence for the economic and social benefits that their solutions bring. That is why some of the authors of this paper have created the independent, neutral and participative French Forum of Living Labs for Healthy and Independent Living (www.forumllsa.org), in order to support this effort towards closer collaboration between stakeholders.

Thanks to this open, ethical yet efficient process, we think that effective and acceptable PHS for older adults will finally emerge and be deployed, generating the public health and economic benefits that they have long been expected to produce.

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