Contribution of the Living Lab approach to the development, assessment and provision of assistive technologies for supporting older adults with cognitive disorders


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Abstract. Many technology-based products and services have proven to be successful in supporting older adults with cognitive disorders in regard to health and social care, safety, and independent living. However, several barriers to effective design, assessment and provision of assistive technologies in this context have been identified over the last years (e.g., technology acceptance and usability issues, methodological limitations in the assessment process, difficulties to balance the interests of different stakeholders, fragmentation in the field, lack of appropriate models for including assistive technology in global care plans). These barriers are associated either to micro-level factors, pertaining to the individual user, or to macro-level factors, related to a variety of stakeholders and the socio-economic, organizational and infrastructural charac-
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This paper discusses how Living Labs in the sector of healthcare, by promoting user-centered approaches, open-innovation, multi-stakeholder alliances and real-life experimentations, offer the infrastructure, knowledge, services and flexibility to address these issues. After summarizing main barriers to the use of assistive technology by older adults with cognitive disorders, we provide a general description the Living Lab concept and some examples of related national and regional initiatives. Then, we present LUSAGE, a French Living Lab engaged in the design, assessment and deployment of assistive technology solutions for older adults with cognitive impairment, such as Alzheimer’s disease and related dementias. LUSAGE’s scope and activities are described in terms of the identification of micro and macro level factors that influence AT development, assessment and provision in this context. Finally, we suggest some promising directions for further development of Living Labs in the field of aging and independent living.

Keywords: assistive technology, aging, cognitive impairment, Living Lab, open innovation, ecosystem

1. Introduction

Assistive Technology (AT) can contribute to independent living and physical, mental and social wellbeing in healthy elderly individuals and in older adults with cognitive disorders (OACD), such as Mild Cognitive Impairment, Alzheimer’s disease and related forms of dementia [PCR+13, BHa08, LHB13, POB+11, RPW+11]. AT refers to any kind of product, service, system, process or environmental modification that can be used by elderly people to overcome the social, infrastructural and other barriers to independence and full participation in society, and to allow them carrying out everyday activities safely and easily [HJo08]. Under this definition of AT fall both mainstream products, that meet accessibility standards to be used by this population, and assistive products, especially designed to meet disability-related needs [HJo08, PMi13].

The range of AT products and services intended to support OACD and their caregivers is wide. It comprises monitoring devices, cognitive orthosis, robotic applications, ambient technology, technology-based support services and communication networks, among others. How-
ever, despite the positive findings observed on the use of AT with this population [PCR+13, POB+11, RPW+11], several barriers to effective design, assessment and provision of AT for this population have been identified over the last years, including:

(a) **Challenges associated to needs and requirements gathering in OACD.** Complex life situations commonly observed in OACD (e.g., impaired judgment, functional disability, presence of co-morbidities, socio-economic vulnerability) explain the necessity of conducting a multidimensional and accurate assessment of their needs with regard to AT. However, there is a scarcity of AT assessment tools and user-research methods adapted to OACD [PCR+13, PBR+13, Pic11, ACM+13]. Additionally, needs assessment is costly and time consuming because it requires professionals with specific training in AT assessment and the involvement of relatives and social and health care practitioners [RPW+11].

(b) **AT solutions often fail to accommodate to the changing and diverse needs of OACD.** AT solutions should take into account the wide heterogeneity of living situations observed in OACD, the progressive nature of deficits, and the presence of fluctuating symptoms in terms of cognitive functioning, behavior, and arousal. The lack of highly adaptive and customizable AT solutions, and procurement methods, minimizes the possibilities to fulfill the needs of these persons [PBR+13].

(c) **Usability issues:** older adults who experience cognitive deficits and age-related changes in perceptual and motor systems may have difficulties to use a technological device or learn a new task. Limited technology experience and negative attitudes towards AT are additional factors that may prevent or hinder the use of AT [BHa08, RPW+11, PBR+13, AFC+05, GZi09, CBo09, MTi05, RBL+09].

(d) **Low acceptability of AT among OACD and their caregivers due to poor "perceived value" of the solution or low product quality** (i.e., effectiveness, reliability, safety and simplicity) [BHa08, MTi05, RBL+09].
(e) Ethical issues, particularly those related to the stigma associated to the use of AT and the risk of compromising privacy and self governance (e.g., rejecting the idea of being "tagged or tracked", lack of recognition of a "felt need" for assistance) [MTi05, RBL+09, PBH09, And07].

(f) Low awareness of existing AT solutions, procurement methods and funding possibilities are factors that slow the uptake of AT solutions by primary users, including OACD, families, informal and formal care providers [PCR+13] [MTi05, And07, SMm11].

(g) Organizational issues within the health system and the lack of an integrative model for AT procurement, training and support services. This set of barriers is mainly explained by the high fragmentation observed among entities working in the sector (e.g., private vs. state, social vs. medical) and the specificities of each territory in terms of actors, allocation of resources, laws and regulations [PBR+13, Pic11, ACM+13].

(h) Difficulties to balance the interests of the different stakeholders concerned by the design, assessment or provision of AT solutions. The lack of a central coordinating body for AT development and provision translates into the difficulty to reconcile engineering, technical, medical, economical, and social perspectives, and consequently hinders the definition of action priorities towards a common goal [PCR+13, BHa08, Pic11, ACM+13].

The aforementioned barriers have serious implications for the different actors of the AT ecosystem. The most critical being that opportunities to improve care quality for OACD and their caregivers through the use of AT products and services are reduced. Also, a commonly observed pattern is that, although major efforts are put into the design and development phases, the deployment of these solutions remain slow [Pic11, ACM+13]. Even more regrettable is the fact that many AT solutions do not thrive beyond the experimental evaluation stage to penetrate into the market, although their interest is well supported by empirical evidence [BBB+11, AAG+11].

A first step to overcome such barriers would logically be to thoroughly examine the needs of OACD and identify factors that may in-
fluence AT usability, acceptance, and adoption. In this paper we will refer to this set of elements as "micro-level factors", because they are mainly related to the individual user. The study of micro-level factors (e.g., user’s needs and characteristics, "felt need" of assistance, usability and accessibility standards, individual context of use, perceived value of the solution, individual ethical standards, etc.) falls under the scope of user-research, which is by nature interdisciplinary. In this regard, participatory and user-centered design approaches appear to be useful because they promote the involvement of potential users throughout the entire design and development cycle of AT solutions (i.e., product design is driven by user’s needs and experience and non inversely)[POs01, FRC+09].

A large volume of studies describes the advantages of actively involving end-users in the development and evaluation of healthcare technologies; "actively" must be understood in the sense of co-creation and not only as the interaction of the user with the new product/service under development [Pic11]. Shah Robinson [sRo07] conducted a literature review on this topic and found that the most commonly observed benefits of this approach are the generation of ideas by users, having a direct access to users’ perspectives, and the improvement of product design, functionality, usability, and quality. Although, the authors pointed out some drawbacks of this practice, such as the difficulty of finding and recruiting a representative group of end-users, time and cost factors, they concluded that the trade-off is worth it because it benefits both users and manufacturers. On the one hand, users will have access to technological products that really fulfill their needs and expectations. On the other hand, manufacturers will increase the likelihood that their products find acceptability on the market.

Among the cited barriers to effective use of AT in OACD we have identified another set of influences that arise this time from the ecosystem. These elements are not consensually defined within the AT literature, but we will refer to as "macro-level factors" because (a) they are linked to the organizational, social, political, economic, and cultural context in which the AT product cycle occurs, (b) imply a territorial dimension (e.g., cities, departments, states, regions), and (c) go beyond the individual/user sphere. Macro-level factors concern multiple stake-
holders: the group of primary users, representatives of health organizations, researchers, manufacturers, policy analysts, economists, regulatory agency representatives, and ethicists. Macro-factors will influence at different points the AT value chain, defined as “the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use” [KMo00]. Macro-factors include thus: infrastructure and services, public health policies, legal and regulatory issues, quality standards, business models, public-private partnerships, awareness raising campaigns and ethical and societal factors. Their study is therefore multi-disciplinary.

To summarize, effective design, assessment and provision of AT for OACD, must take into account micro and macro-level factors related to the individual user and the ecosystem respectively. Consequently, there is a clear need for an approach that promotes technological and social innovation, user-centered approaches, and collaboration among stakeholders, and addresses simultaneously the organizational and infrastructural arrangements of each territory. In this context, the Living Lab (LL) approach appears to offer the architecture, knowledge, services and flexibility to coordinate actions at both levels [PCR+13, Pic11, ACM+13, RSB13].

2. The Living Lab Concept

The LL concept is a complex one, because it refers to an environment, a methodology, and a system, as has been pointed out by Bergvall-Kåreborn and colleagues [BHS09]. These perspectives, that are not mutually exclusive but rather complementary, allow focusing on different aspects of a LL, for example, the constitution of technological platforms and user communities (environment), the emphasis on user involvement, user-centered practices and real-world experimentations (methodology), and the relationships between multiple stakeholders present in a specific territory that works as a whole (system). Accordingly, McPhee et al. [MWL12] have defined LLs as “physical regions or virtual realities, or interaction spaces, in which stakehold-
ers form public-private-people partnerships (4Ps) of companies, public agencies, universities, users, and other stakeholders, all collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts“ (p.3).

The LL concept involves five main principles [BIS+09] that can be summarized as follows:

- **Openness**: the LL is a milieu in which multiple stakeholders cooperate and share their perspectives to foster innovation.
- **Users’ influence/empowerment**: in LLs users are not only actively involved in the innovation process but have also a decision-making power.
- **Realism**: in LLs innovation activities (i.e., creation and validation) are carried out in natural, real-world settings.
- **Value creation**: solutions developed within the LL approach have the potential to better meet the needs of consumers, than those developed within traditional product-centered approaches, and thus to have higher economic, business and consumer/user value.
- **Sustainability**: the LL has an engagement with the community in which it operates. First, in terms of developing sustainable networks for innovation, and secondly, guaranteeing the formalization of knowledge gained through practical experience and its transfer, to ensure its availability for a wider community of stakeholders beyond the local territory.

### 2.1. Local and Regional LLs Networks

Since the LL concept appeared in the 2000s it has considerably evolved from the definition of a particular research infrastructure, a building replicating a normal home equipped with all required facilities that provides temporary residence to experimental subjects who experience during this period different technologies [MRa00], to designate a dynamic multi-stakeholder network aimed to foster and manage user-driven innovation in real world settings. In this respect Agogué et al. [ACM+13] have provided an interesting metaphor of LLs as “architects
of the unknown“ to explain how, among the variety of actors concerned by technological innovation, LLs play an innovation-intermediary role. By acting on the ideas and imaginaries of other stakeholders, and challenging their representations, LLs have the potential of inspiring design efforts and improve stakeholders’ innovation capabilities.

Nowadays, LLs are considered one of the main actors in innovation management. This approach tends to spread in the industrial sector, and in many research laboratories, at various territorial levels (e.g., local districts, cities, regions) [Pic11]. Their growing recognition as initiators and catalyzers of change and cross-border collaborations in different systems (e.g., healthcare, urbanism, public services, manufacturing) explains why LLs networks have gained an increased visibility in the local (France) and regional (Europe) contexts [STu12]. At the European level, the European Network of Living Labs (ENoLL) [Eno00] has largely contributed to the formalization of the LL concept. Created in 2006 as an international, non-profit, independent association of benchmarked LLs, ENoLL supports the creation of a dynamic, multi-layer and multidimensional European Innovation ecosystem, and facilitates the cooperation and the exploitation of synergies between members and external stakeholders. Grown through "waves" of applications it counts today with more 340 accredited LLs in Europe and worldwide.

At the national level, two initiatives have been launched in this area. France Living Labs (F2L) is a French network of LLs that supports user-driven open innovation on a national level [Fra00]. F2L exists officially as an association since 2012 although its members had been conducting annual meetings since 2008. Representing the French chapter of ENoLL, the main goals of F2L are (a) to offer an operational support to LLs members mainly for collaborative national and international projects, (b) to animate the local network of LLs, promote the LL concept and best-practice sharing, and (c) to endorse the ENoLL label and the LL approach by organizing various events.

The second local network is the French Forum for Autonomy and Health (FFAH) [Fre00]. FFAH is one of the outcomes of a working group on LLs in the health and independent living sector coordinated by the High Council for Economy (CGEIET ) in partnership with the French Ministry of Health between 2009-2011. Participant LLs, and re-
lated organizations, joined in 2012 in an informal forum, the FFAH, to federate local initiatives and foster greater collaboration between LLs and other stakeholders working in the field. FFAH allows its members to mutualize equipment and cohorts, share knowledge, and exchange best practices to converge towards common, validated and eventually standardized methods and outcome indicators. Issues addressed by are specific to the health sector and include: the ecosystem, business models, organizational and ethical aspects, laws and regulations, service interoperability, and evidence dissemination. More generally, this informal collective of French LLs enables its participants to make themselves heard more effectively in the public debate and help raise awareness in the general public about what the concept of LL really entails - especially how it goes beyond the experimentation in home-like laboratories and aims to assess solutions in the real world.

Finally, in the French context, it is worth noting that promoting the LL approach for the development and deployment of products and services for the elderly population has been identified as a strategic action for the Silver Economy initiative, launched in early 2013 by the Ministry for Industrial Recovery and the Ministry for the Elderly and Autonomy. Several LLs, in particular LUSAGE, have consequently been very active in the Silver Economy working groups, which associate industry representatives, public policy makers, representatives of patients and caregivers and other relevant stakeholders, to make proposals to support the development and growth of the sector [Rep13]. Although it is not yet known, at the time of writing of this article, which proposals will actually be implemented, it is clear that the integrative and participative nature of LLs is now widely regarded as a very strong asset for piloting the resulting initiatives and coordinating the actions of the various stakeholders in an economically efficient, yet sustainable and ethical way.

3. LUSAGE Living Lab

LUSAGE is a LL specialized in the design, development and provision of AT products and services for older adults, in particular those living with cognitive impairment (e.g., Mild Cognitive Impairment,
Alzheimer’s disease and related dementias), and informal and formal care providers [PCK+12]. LUSAGE activities cover the entire design, development cycle of AT and the identification of micro and macro-level factors that influence AT use, provision and adoption in the population of OACD and their caregivers. For these purposes LUSAGE team has adapted traditional user-research methods to work effectively with OACD. The LL also works in closely collaboration with primary users and other relevant stakeholders in the field of aging, AT, healthcare, and social inclusion.

LUSAGE is affiliated to the Geriatrics Department of the Broca Hospital (Assistance Publique- Hôpitaux de Paris), which provides medical and support services for the management of older adults living with chronic or acute conditions, and to the Paris Descartes University (Research Unit EA 4468). The general mission of this unit is to provide scientific evidence that will contribute to a better understanding of Alzheimer’s disease mechanisms and develop better care strategies for patients and their caregivers, including the use of AT.

At the local level, LUSAGE is one of the partner laboratories of the National Expert Centre in Cognitive Stimulation (CEN STIMCO), launched by the National Solidarity Fund for Autonomy (CNSA). The main objective of CEN STIMCO is to promote the development and use of innovative cognitive interventions, including AT, for individuals living with a cognitive disability. CEN STIMCO encourages stakeholder partnerships and catalyzes initiatives in technological fields and cognitive sciences, supporting projects from their incubation to their entry on the market. LUSAGE is also member of the two national LL networks previously described: France Living Labs (F2L) and the French Forum for Autonomy and Health (FFAH). At the regional level LUSAGE was certified ENoLL in 2012.

3.1. Facilities and Staff

LUSAGE has a flexible architectural configuration that can be adapted to conduct in-situ observations (e.g., home-like setting) according to the requirements of each project (Figure 1). Therefore, it provides a controlled environment for studying the interaction of users with tech-
Projects that require an assessment in real-life conditions can be conducted at the different hospital departments (e.g., Memory Clinic, hospitalization departments, Dementia Care Unit), adult day-care centers associated to the hospital, or in the user’s own environment (e.g., home, nursing home). In-situ remote observations can also be run through the collection of interaction data (e.g., user interacting with a Web or Smartphone application).

LUSAGE has assembled a multidisciplinary team of human factors specialists, psychologists, physicians, engineers, designers, sociologists, and health economists. Associated staff also includes an "administrative and financial board" and a "scientific board" gathering experts from different fields (e.g., geriatrics, technology, human factors, cognitive sciences, law, ethics, public health, etc.).

3.2. Users’ Involvement

LUSAGE primary end-users are OACD, healthy elderly individuals, families, and informal and professional caregivers. These end-users are involved in all the stages of the product development cycle (e.g., needs gathering, usability testing, monitoring studies, evaluation of technol-
ogy acceptance and ethical issues associated with the use of AT). Depending on their motivation and availability, users may participate either occasionally or in regular user-groups. OACD are recruited from the Broca Memory Clinic, Centers for Local Information and Coordination (CLICs), and local Alzheimer’s associations. Healthy elderly persons are usually recruited through local seniors associations. Informal and formal caregivers are recruited through the regional hospital network.

3.3. Stakeholder Network

The LL concept is based on the endeavor to promote cooperation between all stakeholders in the development of valuable and innovative technological products, services, and markets. Therefore, in LUSAGE, primary end-users, large companies or SMEs, policy-makers, research organizations, civic sectors, health insurers, representatives of ethical committees and other relevant stakeholders, are committed to work together to design new AT products or services and participate in experiments conducted in real-world settings. These collaborations are engaged at different territorial levels, ranging from local projects conducted within the city district in which the laboratory is located (i.e., Paris 13th district), to international projects involving partners from other continents.

3.4. Scope and Activities

The design and the development cycle of AT solutions comprises the definition of users’ profile, the identification of their needs and expectations, the iterative development and assessment of the product (e.g., usability and acceptance), the evaluation of the final product, and all the procedures linked to AT provision, implementation, adoption, and follow up. A key feature of LUSAGE’s approach is to take into account and study micro-level factors, related to primary users, and macro-level factors, related to the ecosystem, throughout the entire value chain of AT solutions.

In this sense, LUSAGE plays a role of intermediary between these two levels by acknowledging the particularities of the situation of
OACD and the complex stakeholder network, and corresponding interests, which characterizes healthcare in this context (Figure 2). By applying user-research methodologies adapted to OACD and promoting multi-stakeholder partnerships LUSAGE aims to bring value to each of these partners in an integrative way. Finally, thanks to its neutral and external position, LUSAGE contributes to bridge the gap between the primary user and the stakeholder network providing the conditions for technological and social innovation in a win-win situation.

In LUSAGE, the development of AT solutions is performed in collaboration with primary users and other relevant stakeholders using an iterative design process, in which the product is designed, tested repeatedly and modified according to the observed successes, shortcomings, and impressions, from the earliest phases of product development until a satisfactory level of usability has been achieved. The assessments of initial prototypes (e.g., device functioning, quality, and safety) are usually conducted under controlled conditions; then, when more advanced versions of the systems are available, observations in real-life are carried out to evaluate the effectiveness and actual use of the AT solution (e.g., effects on global health, social participation, satisfaction, quality of care, service improvement, economic value, etc.).

It is important to specify that LUSAGE may participate at any moment of the product cycle, from idea generation to advanced stages of
development. However, its role is not limited to product development. Indeed, thanks to the LL methodologies, LUSAGE has the capacity of following AT solutions that already exist in the market. The instrument that allows this flexibility is the continuous gathering of users’ feedback (Figure 2), made possible by the collection of in-use interaction data and other quantitative and qualitative methods. Continuous gathering of users’ feedback allows the documentation of areas for design improvement and brings new ideas for AT development in a permanent innovation dynamic. From the perspective of other stakeholders, the continuous gathering of users’ feedback enables the identification of difficulties of integration, distribution, and procurement and consequently, the optimization of procedures that will translate in a better uptake of AT solutions. Table 1 summarizes the main projects in which the LL has been actively involved.

3.4.1. *Identification of Micro-Level Factors*

As it was previously described, micro-level factors include all the elements that are directly related to user’s characteristics that should be taken into account for AT design, provision, and adoption. In this section we will briefly describe some micro-level factors that are studied in the framework of LUSAGE projects.

**User’s Characteristics**

The definition of OACD profiles as potential users of AT solutions should consider different domains: (a) cognitive and functional characteristics, in terms of abilities and limitations; (b) possible physical or sensory limitations; (c) everyday needs and requirements; (d) perspectives towards AT solutions (e.g., attitudes, expectations); (e) living situation of the person (e.g., housing arrangements, social network, availability of support services); and (f) lifestyle and preferences.

General guidelines, direct observations, surveys, questionnaires, AT assessment procedures (e.g., Comprehensive Assistive Technology CAT-Model, Matching Older Adults with Dementia and Technology-MOADT Model) [PBR+13, HJo08a, SFT+12] and interviews, are some of the methods that are used at LUSAGE to gather and organize user-related information (Table 2).
User’s Needs and Requirements

Successful implementation of AT in OACD depends greatly on the understanding of user needs and the barriers to technology use that may exist. Users must recognize the need for assistance, be able to make use of the assistive devices provided, and be willing to use and incorporate them in their lives. For this reason, a fundamental step in the design process of AT is to gather the needs of potential users, first, in the early stages of the project, and then at each design iteration, to ensure that the system meets the specified requirements.

At LUSAGE different need gathering practices are used to: (a) identify situations that are problematic for users in a given context; (b) explore the solutions implemented by the persons using the resources at their disposal; (c) determine what needs are not currently being met by the strategies available (e.g., area of difficulty for the person on which no, or an inappropriate support is provided); and (d) create solutions to address these unmet needs through the definition of new system requirements (Table 2).

In co-creation projects conducted at LUSAGE, we aim to identify what end-users truly need and want, regardless of their cognitive impairment. Often, traditional designers tend to assimilate the needs and tastes of OACD with those of their caregivers, particularly when the former are not capable of wording their own opinion. At LUSAGE, we strive to find ways to get feedback from OACD even when it is not possible using traditional user-research methods. We may for example organize idea-generation workshops as plays, where the researchers enact the use of a given solution in front of the users and monitor their reactions, whether verbal or non-verbal. Another solution is to organize testing sessions as recreational activities, the first aim of which is not to gather feedback but for users to have fun. Although these alternative methods may produce less “objective” data than traditional testing, it is of higher interest with OACD, as these users tend to react more naturally and engage more easily than when they feel that they are being scrutinized in a lab setting.
The Role of Informal Caregivers

The majority of OACD receive care from their spouse or from adult children. Hence, one of the goals of AT in this context is to mitigate caregiver burden through different means: by offering caregivers concrete solutions to deal with some challenging behaviors of the patient (e.g., wandering, repetitive questioning, apathy); by providing OACD with cognitive assistance for everyday functioning, task that otherwise would be assumed by caregivers (e.g., reminding events, monitoring activities, ensuring safe use of domestic appliances); and overall, by allowing caregivers to take a break from their caregiving duties in order to take care of themselves.

Involving informal caregivers in the design process of AT for OACD impairment is important for several purposes: to learn more about the primary end-user and corroborate his/her needs; to understand the caregiving situation of the primary end-user and define the role that AT could play in the current distribution of care-related duties; and to specify the caregivers’ user profile because caregivers can directly benefit from AT, and in many cases, they will be required to learn to use and personalize the AT solution at home.

Individual Ethical Considerations

All the projects conducted in LUSAGE require the definition of an ethical and legal framework. This process allows the identification of ethical issues that may arise from the involvement of OACD in the design process, and the evaluation and use of AT solutions. Ethical frameworks describe as well all the procedures required to obtain approval from the relevant ethics committees: the University Paris Descartes ethics committee, the CCTIRS (Comité Consultatif sur le Traitement de l’Information en matière de Recherche dans le domaine de la Santé), and the CNIL (Commission Nationale Informatique et Liberté). In LUSAGE projects, the ethical framework is systematically reviewed throughout the project. Prototypes and methodologies are adjusted when necessary to ensure consistency with the ethical framework defined. Inversely, the framework should be updated and adjusted to take into consideration ethical considerations that result from user research.
For LLs operating in the sector of healthcare, like LUSAGE, the question of autonomy, which is the ability to act according to one’s beliefs and personal choices, is a major issue. The freedom of OACD either to participate in a LL project, or to accept, reject or abandon an AT solution must be respected. Informed consent is thus a central point. On the one hand, individuals with dementia have a diminished capacity for judgment, affecting their ability to make informed choices. On the other hand, the presence of cognitive impairment should not justify the presumption that the person is not capable of any decision regarding his/her life choices. Although involving a third party in decision-making is some cases necessary, LUSAGE’s take on the matter is that given its principles of inclusiveness and user-centric approach, a LL must strive to obtain and monitor consent for any and all users involved. Consequently, adapted consent forms and communication strategies are always used in projects involving OACD. More importantly, reactions that could indicate reluctance to participate, such as repeatedly taking off a geolocalization wristband, are carefully monitored and usually result in exit from the study.

Another major issue in this context is to assure the participation of OACD in LL experiments. The risk exists that AT manufacturers believe that these persons cannot express their needs and preferences because of their cognitive impairment and thus discard their opinions. In our experience at LUSAGE, OACD are often willing and able to participate in the different phases of the AT development. Theirs opinions should also be taken into account because they often differ from those of their family members (spouse, children). Indeed, discarding OACD opinions might jeopardize final AT outcomes and lead to the rejection of AT solutions if they are not tailored to the user’s current needs and wishes.

Need gathering methods enable the examination of individual ethical considerations that influence AT acceptance (Table 2). They also help to determine which characteristics of AT products and services have value and utility for potential users, and to prioritize design actions. From the side of users, the attitudes and opinions towards AT solutions are conditioned by their representations and the self-image induced by their use (e.g., paternalism, stigma, empowerment, self-confidence). These opin-
ions must be heard and respected. Two assessment tools, recently developed in France, can be used to conduct an ethical analysis in this context: the TEMSED, which provides a multi-axial and multi-disciplinary approach to evaluate healthcare technologies at home in six dimensions, including deontology [RSB+13], and the GEMSA, an instrument created to support the evaluation of projects in the field of technology for healthcare and independent living, which includes a section on ethical considerations and user empowerment for decision-making [GPi11].

3.4.2. Identification of Macro-Level Factors

One of the ultimate purposes of the LL approach is to evaluate the actual impact of solutions deployed in the real world. This typically includes public health outcomes such as quality of life, level of public awareness or Disability Adjusted Life Years (DALYs), and economic outcomes such as return on investment (ROI), reduction of public spending or market growth. This macro-level assessment is arguably the most difficult challenge that LLs in the health sector have to tackle, as it requires large cohorts, extensive amounts of data, complex outcome measures and thus substantial resources. It is however also one of their key missions, as results have the potential to impact public policy regarding, among others, procurement, awareness raising, legal and regulatory issues and economic incentives, as well as private funding and distribution opportunities.

To fulfill this mission, LLs must venture beyond the usual technical, usability and acceptability issues that are traditionally studied by user-research specialists. They must become an integral part of the overall healthcare and independent living ecosystem and work to include all stakeholders in the co-creation and assessment process. Stakeholder partnerships that result from the LL principle of "Openness" enable to properly take into account the social, economic and legal aspects which may jeopardize the beneficial impact of AT solution once it has been deployed, even if it performed well in the lab or in pilot experiments and was well accepted by testers. Moreover, with the increasing generalization of integrated care pathways in dementia, which focus on medical and social care coordination, multidisciplinary case management, common tools for screening, and individualized service planning, it seems
fundamental to look at how AT can best be implemented within a holistic care plan. In the following, we present a selection of macro-level factors studied within the framework of LUSAGE activities.

Economical Model and Value Creation

The availability of AT for the greatest number of users (patients, caregivers, associations, professionals) raises the problem of funding. The LL provides a framework to conduct a joint analysis involving relevant stakeholders. Some key issues such as the definition of the role of private stakeholders (banks, insurance companies, pension funds, etc.) and public stakeholders, the recognition of the economic, business and consumer/user value of innovative solutions, prescription and distribution strategies, the legal and political framework of LLs and related sustainability strategies, need to be taken into account in the construction of a viable business model.

The example of economic value seems particularly worth noting as the use of AT in OACD appears to influence economic ROI, but in ways that are very difficult to isolate and quantify, and thus require complex models and large real-world datasets. AT, as it promotes independent living, may have a protective effect on global physical and psychological health. In particular, technologies such as task reminders that allow OACD to carry out independently their daily tasks encourage them to keep walking and moving, which may reduce their risk of developing pressure sores or injuring themselves when they fall. Conversely, AT solutions for social inclusion and communication, such as adapted videophones or collaborative video games, may have a very positive impact on users’ mood and protect them from anxiety and depression, and ultimately slow down cognitive decline. These physical and psychological protective effects are thought to reduce acute hospitalization frequency, among other things, and thus could have a strong economic impact.

However, in both cases, outcomes are complex and difficult to measure, and thus require very large cohorts and long-term studies akin to pharmaceutical studies, which are beyond the financial capabilities of most solution providers. According to the principles of "Value creation" and "Realism", we see the LL approach as a way to obtain these measurements, by relying on the interaction data collected by so-
lution providers, after fairly large scale deployment, allowing policy makers and funding bodies to facilitate the procurement of devices that have proven to have positive ROI with lead users. The use of multi-dimensional assessment instruments for healthcare technologies, such as the TEMSED and the GEMSA may also prove useful to complete the analysis of the economic value of AT [RSB+13, GPi11].

Dissemination, Education, and Sustainability

Regarding dissemination and education on the use of AT for OACD the LL approach offers specific advantages. OACD often experience difficulties to represent themselves as users of AT, which influences the uptake of these solutions. Dissemination campaigns on this topic are scare and primary users, including health professionals, generally lack of awareness on the existence of AT products and services adapted to OACD. The LL approach is especially suitable to this purpose as it allows users to directly experience the benefits of a given AT solution and participate in its customization. Furthermore, researchers can gather data resulting from real-life observations to adapt communication strategies, using adequate language and real-world examples that directly speak to the end users instead of technical specifications that they rarely understand or even are interested in.

Furthermore, with regard to dissemination, LUSAGE offers training on dementia care and the use of AT in this context to engineers, technicians and professionals working in the field of innovation and technology. These educational activities support the mission of knowledge transfer that LLs have, following the principle of "Sustainability" and reinforce the social and ethical engagement of LLs towards the community in which they operate. The participation of LUSAGE in local and regional LL networks is also aligned with these objectives.

Finally, considering that the issue of aging, and especially dementia, remains rather taboo, LLs working in this sector have the potential to contribute to a more positive and inclusive view of elderly citizens and OACD, who desire to continue to participate in society and community life as any other citizen does. The LL framework is especially suitable for this purpose, as its goal is precisely to connect all stakeholders, including the general public, and help them share their views.
in order to reach mutual understanding and cooperate, for example by organizing large scale, participative communication campaigns in public places where people normally gather but scientists seldom show up, such as sport venues, malls, etc.

3.4.2.1. User Empowerment

In LL projects the participation of users as competent partners and domain experts is crucial in the process of co-creation, following the principle of "influence". Older adults’ involvement in an AT design projects depends to a great extent on the value they perceive in the solution, either for them, their families, or future generations. In fact, a feeling of solidarity and the desire of making a contribution to society motivate many older adults that take part in LL projects. Being a full actor in the process of co-construction makes them proud to participate in the innovation process, improves their self-esteem and their feeling of social inclusion. It also contributes to confidence building in using technology, and consequently to user empowerment with regard to AT choices.

4. Conclusions and Perspectives

Older adults are more likely to face loss of independence, social isolation and economic marginalization than those in other age groups. Environmental barriers, activity limitations and participation restrictions are even greater for those living with cognitive impairment. With its recent developments, in particular information technology and ambient intelligence, AT offers various solutions that can help them live more safely and independently in society. However, the design and development of AT solutions tailored to suit their needs is a complex process that must take into account the heterogeneity of the population in terms of abilities, needs, technology experience, interests and lifestyle, and the complex network of actors involved in AT development, assessment and provision and their specific, sometimes contradictory interests.

The LL approach makes it possible to identify micro-level factors, related to the individual user, and macro-level factors, related to the stakeholders network existing in the ecosystem, that influence the de-
sign, development, and provision of AT for OACD. In this sense, we have argued that LLs like LUSAGE promote innovation in an open, inclusive and sustainable way by playing a role of intermediary between these two levels. Throughout the different projects conducted at LUSAGE over the last years, we have confirmed that the value of an AT product results from the co-creation process in which users, caregivers, health professionals, manufacturers, and suppliers all have their part. Successful AT implementation for OACD also implies working together towards the definition of an integrative framework for AT design, assessment, and provision, structured around a multidimensional perspective on user’s needs.

Within the LL paradigm, many previously unsuspected opportunities arise for the sector of AT, thanks in particular to the creative potential of end-users and the long-term efficiency of a properly conducted co-creation process involving all stakeholders. However, in the local context, this is only the beginning, as the most influent stakeholders in the health field have only recently acknowledged the LL approach, in particular public policy makers.

We reckon that now that it has begun to spread, the LL approach will quickly generalize, as it is in essence an autocatalytic process: the more accurately AT designers take into account users’ feedback, the greater the chances become for their solution to meet their needs, reach profitability and spread, generating more quality feedback which, thanks to the LL framework, will in turn feed technological and social innovation, creating a virtuous cycle.

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[Eno00] European Network of Living Labs (ENoLL) http://www.openlivinglabs.eu/

[Fra00] France Living Labs (F2L) http://www.france-livinglabs.fr/


<table>
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<tr>
<th>AT</th>
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Table 1: LUSAGE AT projects
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<td>Prototype design and validation</td>
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Table 2: Methods for User-Research