Valorization of Assistive Technologies for Cognition: Lessons and Practices

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1 Introduction

Cognitive rehabilitation is an important part of the services delivered by the healthcare system and requires increasing human and financial resources from the organizations concerned [1]. It can be defined as systematic therapeutic activities aimed at helping persons with cognitive impairment to regain their functional autonomy. The consequences of cognitive impairment are numerous and include difficulty remembering and learning new things, concentrating, and making decisions that affect one's everyday life. A cognitive impairment is generally classified by order of magnitude ranging from mild or moderate to severe. It can be caused by various types of disease or trauma such as stroke, brain injury, dementia (e.g.

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Alzheimer's disease), multiple sclerosis, tumor, mental illness, etc. Cognitive rehabilitation can take many forms including compensating for the cognitive deficits with external aids (e.g. using a calendar or smart phone to manage a schedule [2]), modifying environmental factors (e.g. turning the television off when doing a complex task such as cooking) and even training the cognitive deficits specifically (e.g. training attentional capacities). One of the limitations of traditional cognitive rehabilitation is its cost. Many authors have noted that the global cost of care for those with cognitive impairment is becoming unsustainable [3, 4]. Furthermore, many of the diseases or traumas that cause cognitive impairment are projected to increase through the next few decades. For example, it is estimated that Canadians living with Alzheimer's disease will grow from 747,000 in 2011 to 1.4 million by 2031 [5]. Similarly, it is estimated that 10 million people will be affected annually by Traumatic Brain Injury (TBI) and, by the year 2020, it will surpass many diseases as the major cause of death and disability [6]. The consequences of these projections are not only monetary. To improve the lives of persons with cognitive impairments, rehabilitation and support services require a lot of qualified human resources. However, in the current healthcare context, such human resources are difficult to provide [7].

Many researchers are now trying to develop Assistive Technologies for Cognition (ATC) with the goal of improving the quality of life of natural caregivers and addressing the resource issues [8]. This objective is backed by the American Congress of Rehabilitation Medicine [9], which encourages the use of external compensatory aids and maintains that it should be standard practice in cognitive rehabilitation. Interventions with ATC offer entirely new treatment methods that can reinforce a person's residual intrinsic abilities. These interventions provide alternative means by which activities can be completed and extrinsically supported. Without this support, those functional activities might not be performed [10]. In addition, ATCs provide continuous support over time that cannot be supplied by healthcare providers, families and close friends. ATCs also support repetitive and continuous interventions without any additional human resource costs, thus increasing the intensity of the rehabilitation. This intensity, which might be obtained in different settings (home, grocery store, etc.), is important to ensure the success of the intervention with persons suffering from cognitive impairments [11].

Work has been done on many projects to enable such assistive services, particularly with regard to the exploitation of smart homes [12–15]. A smart home is a standard house in which different kinds of sensors and effectors are introduced, generally in a non-invasive fashion [16], in order to provide continuous assistance throughout all Activities of Daily Living (ADLs) performed by the residents. Smart homes are generally designed to be a generic assistive service that could ensure safety, autonomy and well-being at all times. However, there are still many challenges to meet for smart homes to become a realistic solution in rehabilitation [17]. Moreover, cognitive rehabilitation generally differs greatly from one person to the next and thus requires adaptable solutions. That is why, recently, many researchers have turned their attention to simpler, yet more specific, assistive technologies [2]. For example, some rely on a single device such as a pager [18] or personal digital

assistant [19]. Another example, developed at our laboratory, DOMUS (Laboratoire de DOMotique de l'Université de Sherbrooke: www.domus.usherbrooke.ca), is called AP@LZ [20]. AP@LZ is a personalized electronic organizer which was conceived to reduce the impact of memory losses in persons with Alzheimer's disease and improve their autonomy. A growing body of literature suggests that ATCs are efficient and effective for improving independence and life participation for people with cognitive impairments [2, 10, 21, 22]. However, ATCs implementation in the field of cognitive rehabilitation remains a real challenge [23]. These intervention tools are still not common in clinics and only a few assistive technologies developed in research reach the commercialization phase [24].

This chapter discusses difficulties with regard to the valorization of ATCs and their widespread adoption. It is divided into three parts. First, it looks at why the implementation of cognitive assistants in cognitive rehabilitation remains difficult. This first part describes the issues at the level of project management, planning, experiments and multidisciplinarity. Second, it presents a specific case of ATC developed at the DOMUS laboratory and analyzes its successes and failures. This second section outlines the various lessons learned through more than 10 years of developing ATCs. Finally, the last section provides a reflective tool to optimize the implementation of cognitive assistants based on the literature. This last section is intended as a general discussion with a view to improving the valorization of ATCs.

2 Challenges Regarding the Valorization of ATCs

Before addressing the challenges related to the valorization of ATCs, it is important to present a definition of what they are. The term ATCs is only broadly defined in the literature. According to Scherer et al. [25], ATCs can refer to very familiar, simple, low-cost devices used by people with and without disabilities to support memory, organization or other cognitive functions, such as paper planners, calendars, alarm clocks, wristwatches and shopping lists. However, in this chapter, we use this term to refer to highly technical devices that compensate for cognitive impairments across environments and task domains. The valorization of ATCs has proven very difficult for researchers around the world and very few concrete products exist despite the amount of literature about ATCs. Valorization can be defined as the transformation of knowledge into concrete new products, services, or processes. The valorization of ATCs thus implies the exploitation of computer science knowledge and models in the development of products in concordance with the knowledge of rehabilitation and professionals. In our case, by valorization we also mean the transition from prototype to adopted product. This step seems to be the most difficult to achieve.

Experts in the field of cognitive rehabilitation have strongly suggested the use of ATCs [2, 10, 21–23, 26]. However, even if the majority of potential users show an interest in assistive devices [23], many challenges preclude their widespread valorization [23]. For the purpose of this chapter, we have divided those challenges

into three main categories that will be described in detail in the present section, i.e. issues related to (1) the nature of innovation, (2) the stakeholders, and (3) the commercialization and marketing of ATCs.

2.1 Issues Related to the Nature of Innovation

The first challenge regarding the implementation of ATCs is related to the nature of innovation itself. According to Mulgan et al. [27], innovation is defined as "New Ideas that Work". An invention that gets adopted and used by a community is what defines an innovation. Thus the concept of innovation goes beyond the ideas and products of research in order to get to the step of their implementation [28, 29]. Moreover, innovation involves the introduction of new practices [30, 31] since practical use is necessary for an invention to become an innovation [32]. The term implementation is therefore defined as a description of "how" the transition from invention to innovation will occur. The very nature of the innovations in the quest to develop ATCs is hybrid, that is, the innovation is simultaneously technological [33] and social [34]. Technological innovations are defined as the introduction of new products or existing products with significantly improved technological characteristics [33]. They are often also regarded as something which was not obvious, as per the rule-of-thumb in the patenting system.

Social innovations can, in turn, be defined as new treatment settings that aim to improve the living conditions of patients [31, 34]. To implement ATCs in clinical settings, clinicians must adjust or even transform their practice. Once developed, ATCs need to go through a thorough process before being provided to users. They can hardly be sold or prescribed to clients with cognitive deficits without a complete assessment of clients' needs by a qualified professional and without several teaching sessions delivered by the same professional. This is in part due to the characteristics of these clients. More specifically, the complexity of matching a person with a technology does not stem only from the individual's unique combination of physical, sensory, and cognitive abilities. In addition, people's expectations of and reactions to technologies are complex and highly individualized. Predispositions to technology usage also depend on one's temperament/personality, subjective quality of life/well-being, views of physical capabilities, expectations for future functioning, and financial/social/environmental support for technology use [25]. Thus, to encourage the use of ATCs, rehabilitation services and technological services (maintenance, updates, etc.) are required and many clinical settings do not possess the necessary resources to adopt new practices related to technology. Today, there are various frameworks supporting the changes in clinical practice (such as the NICE Model [35]) and others supporting the commercialization of ATCs, but none of the frameworks in the literature takes into account the 'hybrid' nature of this type of innovation.

2.2 *Issues Related to the Stakeholders*

The second very important consideration regarding the valorization of ATCs is the consequence of the multidisciplinary nature of these projects. A variety of groups are concerned by the arrival of assistive technologies in cognitive rehabilitation, including healthcare professionals, healthcare administrators, patients and their caregivers. Moreover, computer scientists and engineers generally have a very different vision of how such ATCs should be conceived compared to the vision of healthcare personnel. This is often due to a lack of understanding of the parties involved. Thus, to promote the valorization of ATCs, it is essential to take into account the specific challenges related to the different stakeholders.

2.2.1 Healthcare Professionals, Administrators and the Organizational System Aspect

Many professionals are involved in the day-to-day care of persons with cognitive deficits, including occupational therapists, physical therapists, nurses, neuropsychologists and physicians. This population is currently growing [10], which means a demand for more time and work from the healthcare professionals. de Joode et al. [23] conducted a study which aimed to provide recommendations for the successful implementation of Assistive Technology (AT) in cognitive rehabilitation by investigating the attitudes towards AT of professionals, individuals with acquired brain injury (ABI) and their caregivers. According to that exploratory study, the majority of the professionals working in cognitive rehabilitation showed an interest in AT and were willing to use those tools in the future, especially those who were already integrating technology in their treatment setting. Despite this apparent motivation to increase technology, the reality encountered in the clinical setting is that a minority of therapists currently include it in their practice [23]. Many factors may contribute to this reluctance. First of all, current practice routines are often hard to break [35]. Moreover, these devices are often not covered by health insurance, which limits their adoption in cognitive rehabilitation. The lack of technological and financial supports in the workplace and the time investment needed for professionals to learn how to use AT may hinder their initiative to include them in their treatment methods. This is especially true in the current financial context of the Canadian healthcare system, where professionals are asked to be more efficient with less resources [31]. Finally, a lack of experience, comfort and knowledge about ATCs has a negative influence on the attitude of professionals towards ATCs, and consequently their use. This last factor is especially important to consider as clinician knowledge is one of the key factors that determine whether consumers are appropriately matched to assistive technologies.

Also, these professionals work in a complex system involving administrators and an organizational context [36]. For example, in this context if a professional needs

training to use an ATC, administrators must offer support through monetary compensation and time off. Like all other changes in practice, to succeed organizational barriers must be considered [35].

2.2.2 Patients and Caregivers

As mentioned at the beginning of this chapter, cognitive disabilities such as difficulty conceptualizing, planning, sequencing thoughts/actions and remembering can lead to barriers in performing daily activities at home, at work or in the community. Assistive technology can reduce the effect of these disabilities and improve quality of life [10]. However, before using technology with people with cognitive disorders, it is necessary to understand what their needs are and what barriers limit their use of technologies. According to a study by Kaye [37], persons with disabilities are much less often in contact with computers compared to persons without disabilities, thus contributing to their unfamiliarity with technology. Moreover, a large percentage of those who own devices either do not use them at all or do not use them effectively [10]. The underutilization of ATCs by patients can be explained either by a mismatch between owners' needs and the technology, including inappropriate needs assessments and poor device selection. It has to be considered that users suffering from cognitive disorders often have problems identifying their own needs, which makes it difficult for health professionals to conduct a complete and reliable assessment. Also, psychological factors, which include unrealistic expectations regarding the technology, lack of awareness of one's limitations, lack of support from caregivers, lack of training and lack of information about the benefits of ATCs, often play a role in the poor utilization of ATCs [10, 23]. Indeed, ongoing training and support from professionals is considered vital to the success of compensatory devices [38]. The cost of the technology also has to be taken into account in the list of obstacles that hinder the use of technology by patients [23]. However, although cost is often cited as a barrier to procuring and using technology, users' cognitive and physical impairments add to the challenge [39]. Persons suffering from cognitive impairments are very sensitive to changes in their routines and environment. Finally, the results of a study by de Joode et al. [23] suggest that caregivers sometimes consider the devices as being unsuitable for patients. Also, they often feel they are not properly equipped to support patients with using assistive devices at home.

These challenges were identified by studies conducted many years ago. Since research on assistive devices is currently expanding and technological developments increase their ease of use, portability and intelligence, we can expect that the number of interventions based on ATCs will grow in the coming years. This is especially true at a time when the social trend is to use more and more technology on a daily basis. However, it is important to remember that ATC devices are not necessarily appropriate for all individuals with cognitive deficits. This determination must result from a careful assessment of the person's needs.

2.3 *Issues Related to the Commercialization and Marketing of Assistive Technologies for Cognition*

The last category of issues that need to be discussed is related to the commercialization of ATCs. These issues are also numerous and they represent another barrier to the widespread adoption of assistive technologies (ATs).

First of all, before purchasing an ATC, users or, in some instances, their caregivers have to be convinced that a specific device will meet their needs. Investors also have to believe in a specific product before investing large sums of money to promote its development and deployment. The effectiveness of new ATCs or ATs must thus be demonstrated to those parties. To do so, rigorous studies with good methodological quality must be conducted to evaluate the utility and impact of new ATCs or ATs in the user's real life and over an extended period of time. Unfortunately, most of the studies that evaluated the efficacy of ATCs are of poor methodological quality; for example, they were conducted without a control group or with very few participants [8, 25, 40]. The lack of valid and strong research evidence about ATCs in a real-life context makes it harder for healthcare professionals to promote their use. It can also reduce potential investors' attraction to those devices. Private parties are often skeptical about the functionalities offered by prototypes and only the few that show solid results get through the next phase. Furthermore, there is a lack of studies showing how to successfully implement an ATC in a clinical setting.

Second, it is a real challenge to measure the cost-effectiveness for the healthcare system of using ATCs, and thus the monetary gains related to their use. The effects, direct and indirect, can go beyond a calculation of costs related to their use. For example, improvement in the person's quality of life has been reported [23, 25], as well as improvement in self-esteem, overall satisfaction and emotional stability [41]. Also, the impact of ATCs on reducing caregiver's burden has been reported [25, 41]. For the same reason, it is hard to calculate a good Return On Investment (ROI) or to predict it for the industry. Such a ROI forecast is usually what attracts an investor to provide venture capital. It also means that the business model for ATCs does not necessarily follow a classic product selling paradigm.

Another important consideration is the value of clinical studies in the eyes of private partners or anyone interested in marketing new products. Such studies may hold great interest for scientists but businesspeople generally prefer market research [10]. Additionally, researchers might face more headwinds when trying to partner with relatively large companies. The main reason is that it is often difficult and risky for companies to modify the way they assemble their products. The addition of one simple element can significantly raise production costs or introduce instability leading to lesser quality. To convince them to make the changes required for research or clinical purposes, researchers have to be more concerned about the reality and interest of the industry. Oddly enough, other difficulties may also arise when a company deals directly with the healthcare system, especially if it is public.

Indeed, a public system is a huge machine and changes usually occur over very long periods of time, which can dramatically delay the commercialization of a product.

2.3.1 Marketing in Conjunction with Clients

Currently, many technologies on the market are not designed for people who have cognitive disabilities. While these technologies may sometimes have great potential to assist in daily living, procedures for operating those devices can be complex for a person with cognitive deficits [42, 43]. Any ATC for people with cognitive disabilities must accommodate the individual's skills and deficits. This is complicated by the fact that each person has a unique combination of strengths and weaknesses [10], as well as different expectations, preferences and past experiences with technology. Indeed, aside from their cognitive disorders, these people often have physical and sensory limitations as well. Possible accommodations for people with cognitive disabilities include visual displays with reduced clutter, provision of information in non-text formats (e.g. graphics, video, audio), minimization of the number and complexity of decision-making points, presentation of information sequentially, and reduced reliance on memory [42]. In addition to this complexity, the technology design and prescription also require consideration of all those who will be in contact with the technology, including clinicians and caregivers as well as people with disabilities [44]. Thus, a high degree of customization is often needed for a cognitive device to be effective. Although there are hundreds of millions of people worldwide with cognitive disabilities, the diversity of conditions and situations means that sales volumes for any given product are low and prices are correspondingly high [10]. High prices mean not only that consumers must pay more but also that the growth of the industry is restricted since many potential consumers cannot afford the prices [10].

2.3.2 Insurance

Another major obstacle to the marketing of ATCs is that in most cases medical insurance does not cover their purchase. Consequently, many patients living on fixed incomes are unable to purchase ATCs and/or service contracts and data plans [10, 23]. The current view is that because ATCs (e.g. smart phones, tablets) are not manufactured for the express purpose of compensating for a disability, private insurance companies and Medicare will not fund their purchase [45]. The "who will pay" question is very important but also very complex. One way to overcome these challenges would be to have the product approved by Official organizations like the Food and Drug Administration in the United States. Such a venture would, however, be very difficult and require significant efforts by a research team.

3 AP@LZ: Lessons Learned

The DOMUS laboratory was founded in 2002 with the goal of promoting and developing technological tools to assist persons with limited autonomy and their caregivers. Over the years, many projects have been developed and most of them have been tested with real users suffering from cognitive impairments. The evaluation process includes a usability test, satisfaction poll, evaluation in situ and other means to determine whether the prototype meets the requirements for being released onto the market. However, despite our best efforts and the efforts of many other researchers, the traction of ATCs remains limited.

In this section, we discuss one of the projects we designed with a User-Centered Approach. The evaluation process began in 2010 and is still ongoing. This project, called AP@LZ, originates from clinicians' needs coupled with MOBUS, a prototype previously designed at the laboratory for people with schizophrenia [46]. It falls within the array of various electronic memory aids designed for persons with cognitive impairments [47, 48].

This section is organized in three parts. In the first part, we present an overview of the project and AP@LZ functionalities. In particular, we describe what methods we used to design AP@LZ. In the second part, we outline the various sets of experiments we conducted over the years. The third and last part highlights the lessons we have learned from this project in relation to valorization.

3.1 What Is AP@LZ?

AP@LZ is an acronym that stands for "Agenda Personnalisé pour des personnes avec la maladie d'ALZheimer" (in English: a personalized agenda for persons with Alzheimer's Disease). The first version of AP@LZ ran on a smart phone under a Microsoft system. It evolved to embrace smart phone trends and was then developed on Android to enable more powerful hardware capabilities, such as increased memory, and functionalities. Table 1 presents the development process interspersed with experimental tests.

The development of AP@LZ was driven by the desire to replace a paper agenda that was being used in the healthcare system in Quebec, Canada. The paper agenda compensates for memory losses and deficits in planning but obliges elders with Alzheimer's Disease (AD) to consult it regularly to remember upcoming activities. Furthermore, information entered by elders with AD may not be precise or clear. Thus it is sometimes difficult for them to understand what they have written previously. Clinicians identified these issues and asked for an electronic agenda to be designed that meets elders' with AD needs and is adapted to their abilities. The agenda was designed according to a user-centered approach. A neuropsychologist who had raised the paper agenda drawbacks represented the user. During three preliminary working sessions, the neuropsychologist and computer scientists

Table 1 AP@LZ development and experiments

Development phase	Method	Participants
Version 1		
Participatory design Agile programming	18 meetings	Neuropsychologist
Test in situ	Usage at home for 1 week	2 elders without cognitive impairments
Test in situ	Usage at home for 6–12 months	2 elders with AD
Version 2		
Transfer to new operating system	4 meetings	Neuropsychologist designer
Usability test	2 h in the laboratory	14 elders without cognitive impairments
		8 elders with AD
Test in situ	Usage at home for 2 months	5 elders with AD

discussed the elders' needs and how the new technology could meet them. Based on observations from her practice, the neuropsychologist explained which functionalities and information are essential for elders with dementia to cope with their everyday organization. For their part, the computer scientists presented MOBUS, a mobile agenda that had been designed at the DOMUS laboratory for people with schizophrenia [46, 49]. Some DOMUS functionalities are interesting for people with AD while others are useless or need changes. For instance, MOBUS helps users remember their appointments and activities but does not allow them to enter them by themselves. The activities entered in MOBUS are chosen jointly by the persons with schizophrenia and their caregivers, and entered by the caregivers. As a baseline, a discussion determined what to reproduce from MOBUS and what kind of functionalities were missing in that agenda. It was agreed that the new application needed to be simpler.

To develop the prototype, the programmers followed an agile programming approach [50]. The goal was to develop and get feedback as often as possible in order to improve the prototype at every step. Over the five months of development, the clinicians and programmers met 18 times. At each meeting, the computer scientists presented some prototype interfaces and a discussion followed about what to improve and what to keep. Some challenges arose. On a small screen, for people with AD who have difficulty focusing on the appropriate information, the first challenge was to select the essential functionalities without overwhelming the screen. Another challenge was to design the agenda application: how to record the many types of information necessary to add activities, how and when to alert the user of an upcoming activity, whether to include complex functions such as managing occurrences over weeks or modifying an appointment already entered? A third major challenge was the depth of information processing. The depth, i.e. the

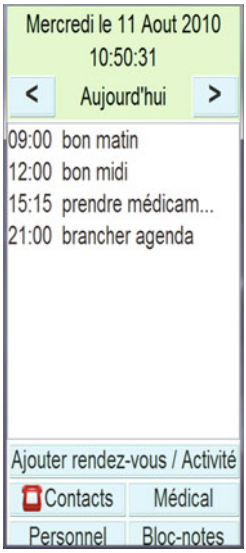

Fig. 1 Homepage of AP@LZ, version 1

steps to go through in various screens to execute a specific task, had to be minimized so that people with AD would not lose track of the purpose of the task they planned to do when using AP@LZ. Eighteen meetings were needed to ensure that the iterative process resulted in a version that both parties found satisfactory. Figure 1 shows the homepage (in French) of AP@LZ, version 1.

The user-centered design resulted in a highly functional version of the AP@LZ application that could be tested by the end users, people with Alzheimer's. With this version we conducted some experiments, which are described in the next subsection, but many researchers on our team still wanted to improve AP@LZ after these initial experiments. The first reason was changes in mobile technology and AP@LZ needed to be transferred to Android to exploit the full power of the features available in new smart phones (we chose Android for its openness and wide adoption). Smart phones not only evolved to include more sensing technologies, they also acquired more processing power and much bigger screens (higher resolution). This provided the opportunity to make the interfaces more attractive by asking the designers to improve it. It was also an opportunity to test some remaining issues concerning how to present information for complex functionalities. For example, we wanted to test the trade-off between showing all the information on a screen needed to enter an activity or displaying the information step-by-step. Another issue was the location and size of the navigation buttons. As the designer team could not solve these questions, we decided to conduct a usability test. The goal was to ensure elders are able to use AP@LZ easily and to determine between different versions of AP@LZ's interface the one they liked best and found easy to use. Twenty-two elders, including eight with AD, tested the AP@LZ interfaces for two hours in our laboratory or at their home. This study led to a final version of AP@LZ that was much more satisfactory and user-friendly (Fig. 2). On

Fig. 2 Screenshots of AP@LZ, version 2

its home page AP@LZ displays time, date, day of the week and planned appointments for that day. Six other functions are accessible from the home page. First, the "Schedule a new appointment" section enables persons with AD to schedule their appointments independently (from a prerecorded system). Second, the "Personal information" section displays, as the name indicates, personal information such as name, photograph, address, phone number, etc. Third, "Medical information" is a section containing the person's medical history and list of medications. Fourth, the "Contacts" page lists the phone numbers of the person's family and friends. Fifth, the "Photos" section allows the user to display a slide show containing some photographs and explanatory text to jog the person's memory. Finally, the "Notepad" section is used to enter any information the user wants to remember.

3.2 Experiments Done with AP@LZ

The AP@LZ application has been the target of many experiments over the years of development and valorization (Table 1). The first experiment was done with AP@LZ version 1. We expected that:

- People with AD would find AP@LZ easy to learn how to use.
- People with AD would use AP@LZ on a daily basis.
- People with AD would improve their daily life organization.

In 2011 [51], the application was pretested with two elders without dementia (or any other abnormal cognitive impairment) for a period of 12–18 days. The goal was

to verify ease of use. It was expected that these elders would encounter no difficulties in using it during this period. At the end of this pretest, participants were asked to comment on their experience. Due to the simplicity of the application, we obtained a lot of comments, which is very rare in usability tests with elders. These comments led to several modifications of the application. This experiment also taught us more about the time required to learn the application. The success rate of the participants varied between 73 and 100 % depending on the task. However, as expected, they reported that they would not want to use AP@LZ regularly as it was too simple.

After getting good feedback from the preliminary experiments, a study in situ was conducted with a population with AD. The protocol was two single-case studies, where we compared the capability for each participant to use AP@LZ and improve their autonomy [52]. The project was approved by the Research Ethics Committee of the CSSS Institut Universitaire de Gériatrie de Sherbrooke, and all participants gave their informed consent. The two participants lived at home with a spouse who gave useful feedback on the elder's capabilities. During a learning period that lasted for about ten weeks with two sessions per week, the two participants with AD learn how to use AP@LZ. This learning period was divided into three phases according to the Sohlberg and Mateer learning method [53]: acquisition, application and adaptation. A good success rate is needed to progress to the next phase. When the learning was completed, the two participants used AP@LZ at home for one year. We periodically evaluated if AP@LZ helped them remember appointments better. As the disease evolved during the experiment, we compared these results with other activities that had not been addressed by AP@LZ. Performances on the tasks assisted by AP@LZ (e.g. remembering to take medication) improved or at least stayed stable over time, compared to performances on tasks not assisted by AP@LZ (e.g. remembering the location of keys). The results of the experiment suggested that (1) persons with AD can learn to use new technologies to compensate for their everyday memory problems, and (2) they can use them efficiently in their day-to-day living if the design remains simple. These results also opened up new rehabilitation possibilities for the population with AD. One of the participants liked AP@LZ so much that he was still using it two years later. With these observations, we tried to promote the application over the consumers market. Our conclusions and lessons learned are discussed in the next subsection.

3.3 Lessons Learned with AP@LZ

AP@LZ has been an enlightening project that has occupied an important place at the DOMUS laboratory over the last few years. We have learned many things that will help in the future development of ATCs. While these lessons are based on experience, our field of research requires such experiments to evolve. We first discuss the two lessons derived from our experience in the conception phase:

- ATCs must be designed using a multidisciplinary approach.
- People with special needs must be involved early in the design process.

The next four lessons concern valorization:

- Software-based inventions are difficult to patent.
- The business model must include support and training for using the ATC.
- Partners do not see the commercial advantages of ATCs.
- Commercialization requires expertise.

3.3.1 Conception

First, we must stress how important it is to involve healthcare professionals in the conception process. Clinicians can share their knowledge and experience when trying to pinpoint the needs and abilities of persons with cognitive impairments. They represent the target population when conceiving a new application. This is valued as experiments take time and people with cognitive impairments have difficulty expressing their feelings. Clinicians can also be the link between computer scientists and people with specific needs. The particular users we target are not easy to approach and need to be handled with care. Clinicians can also act as translators and help computer scientists communicate the information in the adequate language for the persons. However, the question remains whether or not direct contact should be established between computer scientists and clients. Also, clinicians can explain the impact of the cognitive impairments on daily situations. For instance, it would be very difficult for computer scientists to imagine the impact of losses in attention. Therefore, without direct observations of persons with cognitive impairments experiencing difficulties, computer scientists do not have a concrete picture of the situations they are supposed to compensate for.

Secondly, we learned the importance of holding focus groups from the start of a project. They help to link the users' needs and perceptions with the application design. However, recruiting persons with AD for this purpose is not necessarily a good idea. They tire very quickly and have difficulty expressing themselves. We prefer to experiment with people with AD when the application becomes stable. Given the cohort effect and the knowledge of formal and informal caregivers, at the beginning it is better to involve elders without impairments and caregivers in the design and evaluation process, as they are close enough to the target population. Their feelings or abilities when using an application are expected to give a good indication of how persons with AD would behave with the application.

3.3.2 Valorization, Commercialization and Marketing

We tried to valorize this project in many ways after the success of our experiments. The first idea we had was to obtain a patent to protect the intellectual property

developed and also create value for a future private partner. Many difficulties prevented this enterprise from being successful. First, the patent system is not adapted to the scientific process that is based on disclosure to get grants. Second, AP@LZ is software and software is not supposed to be patentable.

We thus decided to find a private partner without a patent. At first we thought that the standard *product selling* model would be the perfect fit due to the simplicity of AP@LZ, but in fact the experiments made us realize that a learning period and the involvement of healthcare professionals in the process are crucial to its success. Therefore, the business plan must include technological and rehabilitation support.

Another aspect that may limit the interest of private partners is the target population. ATCs are usually designed for a niche market so it is hard to convince partners that the model will be profitable. The second thing that we aimed to do was to put AP@LZ in an online store for health-related products. The advantage was that the framework already existed and it seemed a much simpler way to offer it to the population. However, the store was not ready to make the move toward technology. This shows one of the big problems we faced: we are radically changing ways of thinking and therefore encounter strong resistance. We then decided to contact pharmacies directly. We approached a local franchise, pharmaceutical group and even a pharmaceutical provider. Again we received negative comments about potential profitability. In addition, potential partners expressed a lot of fear regarding our business model; they would have much preferred a model that did not include services.

Last but not least, it is noteworthy that some of our difficulties have to do with the expertise of the laboratory itself. We are a multidisciplinary research team but we do not have particular competencies in doing business. Moreover, valorization requires the investment of a lot of time that must be taken away from time devoted to research and teaching. Finally, from the valorization efforts made for this project, we learned that technological improvement is upsetting the way things work in business and in healthcare. We need to work toward convincing people that it is worth trying.

4 Framework for Valorization

As mentioned earlier, ATCs have the specificities of being both technological and social innovations. Therefore, transitioning successfully from research laboratory to marketplace needs implementation strategies that consider these two aspects and their complexity. For example, it is necessary to have a better understanding of technology promotion and complex challenges related to the implementation of a new rehabilitation practice in the healthcare system [35]. In this section, we present a theoretical model for technology transfer, a framework to help understand the process of implementing new practices in the rehabilitation domain, and finally a reflective tool to facilitate the valorization of ATCs.

4.1 Closer Look at Valorization

The term valorization can vary depending upon the context. In general, technology transfer is an expression widely used in many domains rather than valorization. According Lane [54], the valorization process of a technological product like an AT involved three main stakeholders groups in our societies, government, academic researchers, and manufacturers. Moreover, the collaboration between these groups to pass with success from research laboratories to marketplace is a complex process partially due to the different barriers like working method, domain's cultures and values [55]. To optimize the chance of success of this process, Flagg et al. [56] have proposed a conceptual model (The Need to Knowledge model, NtK) composed of three "phases", nine "stages" and nine "gates" (see Table 2).

In this model, Lane puts the knowledge like the core of the valorization process of technology product. He states that the latter consist to "transform knowledge about user's problems from conceptual ideas into knowledge embodied as technology-based solutions" [56]. According to the NtK model, this transformation is composed of three consecutive phases:

- First, there is a "discovery phase", which is the step a research activity (ex: literature review, brain storming, etc.) conducted to find a solution to the user' problematic. The researcher or team of research for example try to identify a new concept or technology that already exists and match it to the user needs. For example, DOMUS team worked in this type of phase to identify the concept to create an electronic organizer to help people with AD to manage their daily activities using a mobile phone.
- Secondly, there is an "invention phase", which represents the period of time when engineering methods have to use to develop a functional prototype of the results of discovery phase to allow the demonstration of the feasibility of the concept.

Table 2 The Need to Knowledge model [56]

Phases	Stages and gates
Discovery	Stage 1: Define problem and solution
	Stage 2: Scoping
	Stage 3: Conduct research and generate discoveries = discovery output
Communicate discovery state knowledge	
Invention	Stage 4: Build business case and plan for development
	Stage 5: Implement development plan
	Stage 6: Testing and validation = Invention output
Communicate invention state knowledge	
Production	Stage 7: Plan and for production
	Stage 8: Launch device or service = Innovation output
Communicate innovation state knowledge	
Production	Stage 9: Life-circle review/terminate?

- Third, there is a "production phase", which occurs when the functional prototype is ready to be transformed into a marketable product for a mass quantity by performing a battery of tests (e.g.: quality control) and refining the design of the prototype (e.g.: marketing service) in order to have a final product matching with the objectives of the industrial actor.

For Lane, it's necessary to guide the valorization process with efficacy and efficiently due to the different stakeholders involved. Three "stages" and three "decisions gates" composed the phases (discovery, invention and production) to support the progression in the transformation process of an idea into a marketable product. The stages are like special elements that allow the stakeholders to determine the project needs to realize. The decisions gates are similar to checkpoint that permit to verify according the state of the project if it possible to go to the next stage.

4.1.1 Implementing Changes in Rehabilitation

The valorization process is complex. Various actors are involved including academic researchers, students, engineers and healthcare professionals. To implement ATCs in the healthcare system also means changing the practice of professionals. Changing established behavior is very difficult because of the complex relationships between the healthcare system, professionals, patients and carers [35]. However, to foster the process of valorization or maximize the success of ATC use by users (people with disabilities, carers, healthcare professionals), we need to understand how to change practices in the rehabilitation field.

Chaplin [35] developed a model (see Table 3) to improve patient care through changing healthcare professionals' and managers' practices. He suggested that the development of a successful strategy for change is based on an understanding of the types of barriers occurring in healthcare, and different ways to overcome them.

Table 3 Change practice model in the rehabilitation domain [35]

Barriers faced in healthcare	Strategies to change
• Motivation	• Educational materials
• Awareness and knowledge	• Meetings
• Acceptance and beliefs	• Clinical audit and feedback
• Skills	• Outreach visits
• Practicalities	• Patient-mediated strategies
	• Reminder systems
	• Opinion leader

According to NICE [35] there are six types of barriers in the process of adoption of the innovation by healthcare professionals. These barriers are:

1. Awareness and knowledge—Identify what needs to change and why
2. Motivation—External and internal factors involved in changes
3. Acceptance and beliefs—Attitudes and beliefs which have an influence on the behavior
4. Skills—Feeling about abilities to use
5. Practicalities—Availability of structures, processes, facilities, equipment and human resources
6. Out-of-control barriers—Societal or social variables such as public policy or organization structure.

The NICE [35] model contains six ways to overcome these barriers: (1) Educational materials (e.g. booklets, journals, CDs, videos and DVDs, online tools, computer programs) and meetings (e.g. conferences, workshops, training courses and lectures) used in combination are effective in changing behaviors; (2) Educational outreach visits or academic detailing according to needs; (3) Exploiting opinion leaders to motivate and inspire healthcare professionals to achieve the best possible care for patients and to foster the dissemination of information; (4) Employing clinical audit and feedback to collect data about individual or organizational practice to improve quality; (5) Use of reminder systems to provide healthcare professionals with specific information when they need it (e.g. during a patient's consultation); (6) Use of patient-mediated strategies to focus on giving information to patients and the wider public. The valorization process must consider all of these barriers to adoption of the ATCs and should also consider using these ways to overcome barriers [35].

4.1.2 Aspects to Take into Consideration for Valorization

In order to valorize assistive technologies for cognition, many important aspects must be considered. Some of the most important are:

- **Research team's goals**: Does the team wish to create a technology (academic point of view)? A product (business point of view)?
- **Technology targets**: What kind of people are addressed by the technology? Are there multiple users for the ATC?
- **Business opportunity**: What kind of market is targeted? Are there possibilities to broaden the targeted end users? Is packaging possible?
- **Partnerships**: What types of collaboration are involved in the project (all private, public-private collaboration)? Who are the end users to convince?
- **Involvement of healthcare system**: What are the impacts associated with the use of ATCs on healthcare professionals' practices? How can practices be changed to foster the use of ATCs in clinical settings?

To answer these questions, we propose a guide to help research teams optimize the valorization process of their ATCs. We assume that research teams want to introduce their technology into the marketplace to address unmet needs of people with disabilities.

4.2 Proposed Tool: Stop and Think Prior to Creating ATCs

In this section, we propose a simple guide called "Stop and think prior to creating ATCs" that aims to help researchers move toward the valorization of the ATCs they develop. We chose the 'Stop and Think' expression because it is a cognitive strategy from Etscheidt [57] for changing ways of thinking: stop and think before any action. We decided to work on such a tool after finding that the difficulty with diffusion and marketing of ATCs was generalized [23]. Many problems occur at the implementation stage, one of the most important steps to prove the value created by the ATCs. It is often the consequence of not very rigorous procedures from a scientific perspective: inconsistency in the terminology used, lack of details regarding the strategies, missing theoretical frame of reference, etc. [58]. The current consensus in the literature is that it is a good idea to base the valorization of technologies on knowledge transfer models to increase the chances of success [56]. Other authors suggest that to ensure the success of the enterprise, the implementation must begin with good planning right from the start of the project [23, 58].

This tool, shown on Fig. 3, is designed to be used even before having a first working prototype. It lays the groundwork for seven key questions related to the valorization planning process, based on the literature and the experience of the DOMUS laboratory team. It also aims to provide potential solutions to these key questions. Each of the following subsections addresses one of these questions.

4.2.1 Who Will the End Users of This ATC Be?

To foster the implementation of technological innovations, researchers need to plan the procedure carefully. The end users and clients who will use the ATCs in the future need to be considered and personalized strategies designed accordingly [23, 33]. The particularity of ATCs is that the target users are generally varied and involved in the project to different degrees. They are the patients, the healthcare organization, the caregivers and the managers (directors, etc.). It is important to understand who are the clients and make them the priority. With ATCs, it is also important to understand that the project may involve the managers, political leaders and often private companies.

Another important consideration concerns the objective of developing an ATC. If the goal of the research project is to introduce the technology into the marketplace, the manufacturers may be considered the real customers of the product. Bauer and Lane [59] explains that manufacturers have the capacity to produce,

Stop and think prior to creating ATCs

Questions to ask prior to creating ATC to facilitate valorization:

1. *Who will the final users of this ATC be?*
2. *What are the users' needs?*
3. *How will the research process be conducted?*
4. *Where will the ATC be in a few years?*
5. *What will the business model be?*
6. *How can you make your ATC more attractive?*
7. *Which valorisation model best fit the context?*

The guide and this tools are available on the Domus web site: http://www.domus.usherbrooke.ca/

Fig. 3 The "Stop and think prior to creating ATC" guide

distribute, and support products in the marketplace, including those designed for use by people with disabilities. In this case, what roles are played by other actors such as research collaborators and healthcare professionals? According to Bauer, they are stakeholders who may influence the research activities and commercialization outcomes. Finally, the research team must address manufacturers' needs while keeping in mind the end users' perspective.

4.2.2 What Are the Users' Needs?

The second question that must be answered is what the users' needs are. One of the intuitive ways to answer it, at least from a researcher's perspective, is to do a literature review. It is even more important when the client is a person with a cognitive deficit. The consequences of cognitive deficits are diverse and ATCs must often be adapted to the specific profiles of the target population. Despite this, we also suggest conducting interviews with the users. Such interviews often give the team a lot of crucial information and also enable a good match between the person and technology.

The families of the end users also play an important role in the project. Since they often act as natural helpers, they might participate in the learning and utilization of the ATC. Their needs must, therefore, be considered. One of the ways to better understand both the needs of the families and the end users is to rely on information from the professionals in clinical settings. These professionals are often a very good intermediary to translate the needs into a language the researchers understand. One of the objectives that all the potential users of an ATC share is support at home for persons with disabilities [60].

Finally, it is also very important to know the needs of industry, which often focuses on mass production and low costs. Thus it is important to keep the technologies simple and not too personalized, to allow, for example, another population to use the same technology.

4.2.3 How Will the Research Process Be Conducted?

To develop ATCs, one of the best approaches is to use participatory action research [61]. This approach involves the users (patients, families, managers, professionals, etc.) in the research process. One of the assumptions of this approach is that future users can provide the project with unique expertise. More specifically, they shed a different light on the needs that the technology is trying to meet. Involving them in the process should guarantee that the technology will be useful and efficient in the future. In a study published in 2007, Landry et al. [33] concluded that the more researchers and practitioners (i.e. end users) invest in continuous collaboration through exchange and discussions, the more the data collected from such research will be used.

A very important point underlined by the work of Frank Lopresti et al. [10] is the impact of undertesting an ATC. ATCs should be tested with real patients with cognitive impairments despite the difficulty of conducting such research (ethics committee, recruitment, etc.). The experiments should also take place in a realistic environment. The environment has a lot of influence and results obtained in a laboratory context could be biased as a result of environmental stress. Moreover, it is a good idea to involve healthcare professionals in teaching and integrating the ATCs in the person's real-life context.

Finally, it is important to be careful about the inclusion and exclusion criteria when recruiting participants. A sample should be representative of the target population. In other words, a person should not be chosen only to facilitate the progress and success of the experiments.

4.2.4 Where Will the ATC Be in a Few Years?

Valorizing an ATC is not a simple task. It is important to establish a clear vision and specific objectives before starting a project. The researchers should take the time to understand and pinpoint their own motivations in the project. They should

know where they want to go and set a number of long-term objectives associated with their research [59]. For example, suppose one is working in ambient intelligence. If the subject being worked on cannot yet be implemented in a house, the ultimate goal of the project remains a research issue regarding the conception and development of the idea [62].

4.2.5 What Will the Business Model Be?

When it is established that one of the objectives of the project is to introduce a product to the market, the research team must define a clear idea of the business model. It is important to convince future private partners (e.g. manufacturers, industry). A business model or plan is a written statement that describes and analyzes the business to be launched. Most private collaborators or investors require a business plan before even considering a proposal. Two points need to be taken into consideration by the research team when establishing the business model:

Target market of the ATC:

The cognitive impairment market is generally small and highly fragmented. Frank Lopresti et al. [10] reported that the diversity of conditions and situations means that sales volumes of assistive technology are too low and prices are correspondingly high. With the goal of fostering commercialization of an ATC and convincing private partners, the research team must determine if they wish to target a specific market for people with cognitive impairments, with the limitations associated with it, or find another type of market. According to Frank Lopresti et al. [10], there are three different opportunities to facilitate commercialization of products. First, they think that using mainstream products to develop ATCs can achieve the low prices that come from high volumes. Second, they suggest that ATCs can be developed using mainstream components as a base. Third, new mainstream markets can be created by the industry actors, taking into consideration which particular characteristics are common to people with cognitive impairments.

Method to sell the ATC:

Transforming a research project on technology into a commercial product is a complex process. An ATC is an assistive product to help people with disabilities in their daily lives. Consequently, its availability in the marketplace needs to be supervised by healthcare professionals. Research teams have to think about this process. Who prescribes the ATC? Physicians? Clinicians? Hospital? Next, the marketplace needs to be defined. Would the ATC be sold in a drugstore like medication or in a hospital?

The costs of the ATC also need to be taken into consideration. Mason et al. [63] reported that ATs are costly to purchase or maintain. With the goal of fostering their usage, it is necessary to determine who will pay for the ATC: Government agencies? Private insurance? End users? Other actors? Solving this question may have an influence on the success or failure of the valorization process. ATCs, like other

products that include services, need to have a customer service to help end users if necessary; for example, if the ATC breaks down or needs to be updated. Who will take on this role: Manufacturers? Research team? The same questions can be asked about the training period necessary for the end user to master the ATC. Healthcare professionals need to spend time to learn the functionalities of the ATC and then how to help the end user learn those functionalities. The research team with collaborators also needs to think about who will pay for this time spent by healthcare professionals: Manufacturers? Government agencies? Hospital? End users?

4.2.6 How Can You Make Your ATC More Attractive?

If the participatory action research approach is selected for the project, questions must be answered regarding the specific expectations users will have about your ATC. Which technological platform should be exploited (tablet, pc, smart phone, etc.)? It is important to keep in mind the simplicity and ease of human-computer interaction. Marketing has something to say about the design of attractive software.

Landry et al. [33] identified the determinants of the implementation relative to the innovation itself (not considering the context).

1. Relative advantage: the innovation should create a significant improvement
2. Compatibility: there should be a coherence between the characteristics of the innovation and the context
3. Complexity: it should be easy to understand and use
4. Experiments: it might be interesting to provide the opportunity for professionals to use the innovation during a trial period
5. Observability: ease of perceiving the effects of the innovation
6. Adaptability: possibility of adapting to the context
7. Radicality: level of changes brought about by the innovation
8. Multifunctionality: possibility of using the innovation in a different context for a different clientele
9. Legitimacy: relates to the adoption by neighbor organizations.

4.2.7 Which Valorization Model Best Fits the Context?

As mentioned previously, the lack of rigor in the valorization process, the lack of common terminology and lack of a frame of reference guiding the process are often reasons for implementation failures.

Answering the previous questions should help in the choice of a good model specific to the ATC. As there are several models, the context must be well known to achieve a good match. Here are some examples of models found in the literature. As shown in Table 4, they are matched against different contexts of development and ATC implementation.

Table 4 Example of models matching the context

Context of development and implementation	Example of models found in the literature
Development and implementation toward the industry	Transferring R&D knowledge: the key factors affecting knowledge transfer success: Cummings et al. [64]
	A model for technology transfer in practice. Gorschek et al. [65]
Development and implementation in public healthcare and practice changes for the professionals	Ottawa Model of Research Use. Graham and Logan [66]: innovations in knowledge transfer and continuity of care
	PARiHS Framework: Promoting Action on Research Implementation in Health Services Kitson (1997) [67]
	Conceptual Model for Considering the Determinants of Diffusion, Dissemination, and Implementation of Innovations in Health Service Delivery and Organization. Greenhalgh et al. [68]
	Innovation dans les services publics et parapublics à vocation sociale. Landry et al. [33]
	Organizational Transformation Model. Lukas et al. (2007) [69]
Development of ATC toward mainstream products	Need to Knowledge (NtK) Model. Flagg et al. [56]

5 Conclusion

This chapter discussed challenges with regard to the valorization of ATCs. We began by describing the main reasons leading to the failures of valorization. We discussed the issues related to the nature of innovation, the stakeholders and the marketing/commercialization of the ATC. We thus set the scene for how complex the valorization of ATCs is.

The second section described AP@LZ, an intuitive and interactive agenda aimed at replacing a paper agenda. AP@LZ was one of the most important projects at the DOMUS laboratory and the one that was nearest completion and ready for commercialization for many years. The lessons learned with AP@LZ showed us that a research team needs to have a broader vision of the assistive technology project which goes beyond “academic research” to include “business culture”.

Finally, we proposed a simple guide for the valorization of ATCs. We discussed the importance of taking the time to think about all the implications of the assistive technology project at the very beginning of the project. The guide reviewed seven important questions that, if answered, should foster the success of valorization. However, due to the complexity of the process, it is highly likely that no guide can ever guarantee the success of such an enterprise.

The DOMUS laboratory is currently leading a large-scale project that exploits the ideas expressed in the guide in this chapter. The use and results will be documented in the future. This should enable us to assess the efficacy of the proposed solutions.

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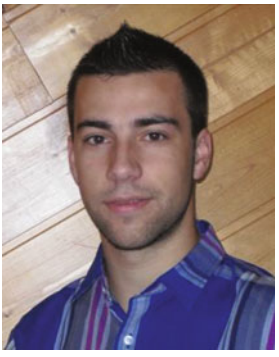

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