Parental control reversed: Using ADR for designing a low-cost monitoring system for elderly

Completed Research Paper

Tobias Mettler
University of Lausanne
Swiss Graduate School of Public Administration
Rue de la mouline 28,
1022 Chavannes-près-Renens, Switzerland
tobias.mettler@unil.ch

Michael Bächle
Baden-Wuerttemberg Cooperative State University Ravensburg
Department for Management Information Systems
Marienplatz 2, 88212 Ravensburg, Germany
baechle@dhbw-ravensburg.de

Stephan Daurer
Baden-Wuerttemberg Cooperative State University Ravensburg
Department for Management Information Systems
Marienplatz 2, 88212 Ravensburg, Germany
daurer@dhbw-ravensburg.de

Andreas Judt
Baden-Wuerttemberg Cooperative State University Ravensburg
Department for Informatics
Fallenbrunnen 2,
88045 Friedrichshafen, Germany
judt@dhbw-ravensburg.de

Abstract

Demographic change and continuously increasing spending on public health have intensified the public debate as well as deliberations on the development and deployment of new assistive technologies for health, independent living, and well-being for senior citizens. Other than large- scale, policy-driven health initiatives that envision ambitious and risky "grand designs", in this paper we illustrate the case of a grassroots-like project which used Action Design Research (ADR) as guiding research paradigm to produce a low-cost, yet effective, monitoring system for people with mild cognitive impairments or dementia. Besides a description of meta-requirements and solution components, we also identify general implications for future research. In particular, we explain how an ADR- inspired approach to social innovation could be a useful alternative to large-scale, policy-driven health initiatives to increase the time-to-market of new solutions, pre-test new use cases, and to enhance accessibility and affordability of assistive technologies for the local community.

Keywords: Action design research, remote monitoring system, dementia, ambient assisted living, civic action, chatbot

Introduction

Given the demographic changes that developed countries are facing in the next decades, the cure and care of elderly is a significant problem for many public decision makers these days. In fact, providing health to a rapidly aging population with fewer resources has become one of the grand challenges of this century for many governments (Joint Institute for Innovation Policy of the European Commission 2012). Despite an ongoing debate whether health information technology (HIT) is effective and efficient enough to deal with this societal issue (Jones et al. 2012), there are generally high hopes and aspirations of policy makers and futurists that technological innovation may solve, or at least minimize, parts of the problem (Hedberg and Morosi 2015). Building upon this premise, almost $20 billion was appropriated for facilitating the adoption and renewal of health technology in the United States during the previous presidential administration (U.S. Congress 2009). Likewise, in Western Europe the modernization of the healthcare sector is estimated to grow in spending from $13.2 billion in 2013 to $14.6 billion in 2018 (IDC 2015).

A matter of particular urgency on the agenda of many of these public HIT initiatives, such as the Active and Assisted Living (AAL) program of the European Commission (2017a), is to sponsor technological solutions that increase the quality of life, autonomy, or social participation of elderly people in order to significantly reduce the costs of health and social care in the long term. Although such initiatives have considerably rushed the development and innovation activity of companies and research institutions towards *assistive technologies* (AT) for elderly people, it still failed to achieve large-scale social and economic impacts (European Commission 2013). The reasons for this are manifold.

First, distribution of funds is typically organized by means of competitive project application processes. The amount of time and effort to prepare a convincing project proposal is significant, which has frequently prevented innovative small and medium-sized companies (SME) or universities to take part in this contest and has favored large private-public-partnerships (PPP), coordinated by big multi-national corporations, instead. Moreover, priority is given to projects, which promise bold solutions and pledge to tackle as many goals of the HIT initiative as possible (Lippeveld and Sapirie 2000). Even though these HIT initiatives implement exigent and rigorous evaluation procedures–for project selection and impact assessment–requesters of funds typically are not held liable for not fulfilling their complete end of the bargain. Accordingly, the chance of overpromising is high and has led to a phenomenon what Charette (2005) referred to as the *liar's poker*.

Second, due to the high up-front effort of the funding requesters as well as the policy maker's–unconcealed or hidden–intention to boost the commercial exploitation for the purpose of employment creation (European Commission 2017a), technological solutions developed in policy-driven innovation programs frequently follow commercial interests with strong intellectual property (IP) protection, which are not necessarily favored by the targeted group of elderly people.

Third, in order that the developed solutions can enter the highly regulated market of medical devices, they need to undergo a complex, lengthy, and costly approval process (European Commission 2017b; U.S. Food & Drug Administration 2017). This again raised the barrier for innovative SME and research institutions as well as ultimately increases the timespan for the solutions to enter the market. On the positive, this has led to high reliability designs which have significantly improved patient safety (Emanuel et al. 2008).

Besides the mentioned policy-driven innovation in the AT domain, there has always been *social innovation*, which has rather emerged from individual interests or personal needs of engaged citizens or civil servants (Sabato et al. 2017). While such pluralistic, decentralized, bottom-up civic actions—because of limited prospects to achieve high impacts, fewer possibilities to exert regulatory control, or unknown collaboration structures—have been less on the radar of public decision makers (Windrum 2008), they nevertheless can lead to purposeful solutions for people in need of assistive technologies (Buntz 2014).

In contrast to the traditional top-down approach, projects based on civic actions often succeed in developing low-cost, custom-built artifacts based on principles of participatory design, open standards and already existing components due to the limited funding available and/or capabilities of the involved participants (Hurst and Tobias 2011). In addition, since these projects are emergent and exploratory in nature—typically following a trial-and-error-learning strategy—the risk of "unproductive" IT investments is comparatively small. Also the higher willingness of patients and family members to engage in such a project setting, frequently leads to richer, more contextualized solutions (Shah and Robinson 2007).

However, a major downside exists as the involved parties have less resources and knowledge to transform and disseminate custom-built prototypes into mass-scale products and services and therefore rarely attain a high outreach with their endeavors. Particularly this has created hesitation among public decision makers to consider and integrate social innovations (or innovation driven by civic action) in their overall plans to tackle the challenge of providing efficient yet affordable AT for the elderly (see Figure 1.).

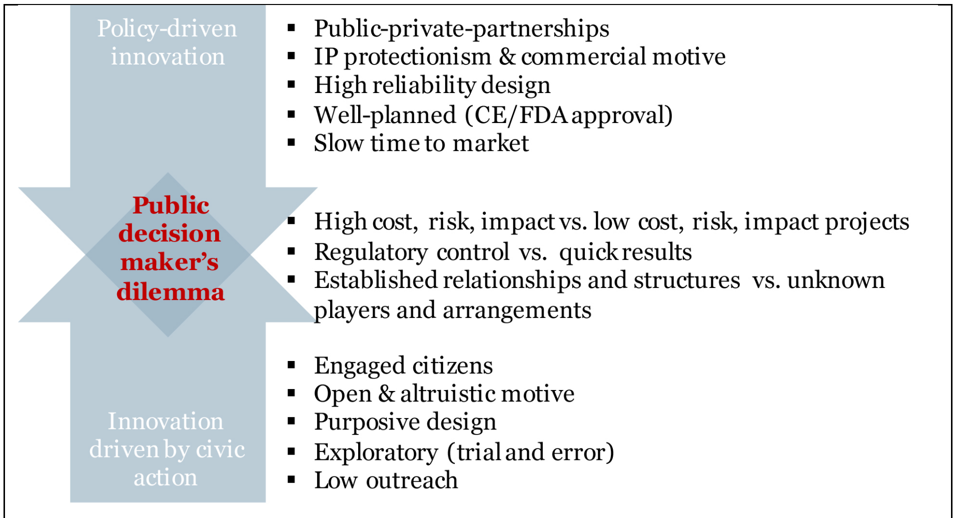

Figure 1. Public decision maker's dilemma

Placed in this tensional context of policy-driven innovation and civic actions, in this paper we describe the development of a low-cost monitoring system for people with an increased need for care, such as people with mild cognitive impairments or elderly suffering from dementia. We do so because existing monitoring solutions for this group of people are either expensive, proprietary, extremely complex to handle by laypersons or not expandable to the needs of family members and caregivers (see *problem description*). Following a pragmatic epistemology and using Action Design Research (ADR) as guiding paradigm in our research, we illustrate how we elicited the requirements, built and pre-tested the prototype, and intend to further evaluate it in practice. Our results leave us cautiously optimistic that an ADR-inspired approach to social innovation is a useful alternative to large-scale, industrial focused research in the area of AT—at least as testbed for the ex-ante evaluation of particular use cases or as inspiration for defining the future political agenda which is subsequently implemented by means of competitive project grants.

In what follows, we briefly describe our methodological approach, which is followed by a characterization of the context of our study. After briefly explaining our research ecosystem, we then describe the major solution components of our low-cost monitoring system. This is followed by a reflection on the practical and theoretical learning outcomes and a final discussion concerning the practicability and limitations of ADR to attain meaningful social innovation.

Action design research as guiding paradigm for social innovation

Designing a monitoring system for people with mild cognitive impairments or elderly suffering from dementia is a real-world problem that requires both, a technological and social viewpoint. On the one hand, we need to understand the possibilities and limitations of existing technological components and their potential use environment. On the other, we need to get a grasp on what is ethically and aesthetically feasible, desired, and acceptable for the affected person him/herself as well as for the involved family members and caregivers.

In approaching this problem, we chose to follow a pragmatic epistemology (Goldkuhl 2012). The essence of pragmatic research lies in the interplay between actions and change: To alter certain aspects of reality, actions are required. Knowledge (e.g., natural laws, social norms, empirical evidence) is essential to change reality into a desired end-state. Actions and their impact can also contribute to further cognitive clarification and development. This contrasts with, for example, purely descriptive research that primarily seeks to explain reality by using models (or a structure of relations) and which uses methods that emphasize the discovery of new knowledge and verify existing (structural) knowledge without deliberately distorting reality. In this sense, pragmatic research is multi-plural (Loos et al. 2013) and problem-driven research (Pohl 2008) by necessity since complex problems do not respect philosophical, historical, or disciplinary boundaries of science.

A research paradigm that combines a systematic thinking for designing artificial solutions with a human-centered lens regarding emergent social dynamics from technology use is *action design research (ADR)*. Preceding a lengthy discussion about the similarities and differences of action research (AR) and design research (DR) (Cole et al. 2005; Iivari and Venable 2009; Järvinen 2007a; Rossi and Sein 2003), ADR was first mentioned by Iivari (2007) and has lately been popularized by Sein et al. (2011) as a predestined approach to fulfill the dual mission of the IS discipline to investigate the *development* and *use* of IT-enabled artifacts in socially loaded contexts (see Figure 2).

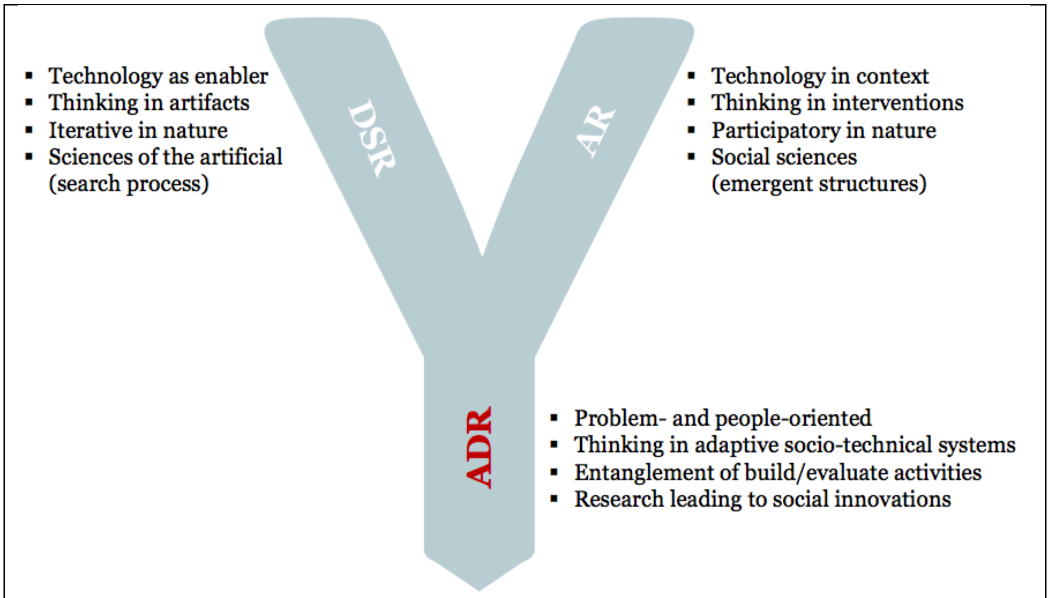

Figure 2. Convergence of DSR and AR into the ADR paradigm

Similar to DSR, which perceives technology as enabler for extending the boundaries of human and organizational capabilities (Hevner et al. 2004), ADR equally addresses the urge to design, use, and refine novel and useful artifacts. The term *artifact* is used to describe something that is artificial, or constructed by humans, in contrast to something that occurs naturally (Simon 1996). To be considered as a science, the creation of such artifacts needs to be systematic and produce new generalized knowledge about, and with design (Baskerville 2008). Rooted in the basic principles of the sciences of the artificial (Simon 1996), this procedure is *iterative* (Hevner et al. 2004; Nunamaker et al. 1991; Peffers et al. 2008; Walls et al. 1992) and follows an incremental search process for mapping the problem space (i.e. real-world problems) with the solution space (i.e. proposition to solve real-world problem).

Similar to AR, organizational intervention and contextual factors play an important role in knowledge creation (Avgerou 2001; Davison et al. 2004). While the researcher guides the initial design, the artifact emerges through the interaction between the development and *use* in context (Sein et al. 2011). Capturing the *emergent* structures emanating from artifacts and reflecting about anticipated and unanticipated designs is frequently a *participatory* process (Avison et al. 1999; Baskerville and Wood-Harper 1998; Mettler 2017) between the researchers and affected stakeholders (e.g. the user him/herself or involved third-parties). In doing so, AR seeks to link theory with practice and thinking with doing (Susman 1983).

Common to both approaches and ADR is the fact that findings discovered during the design and use of the artifact should be generalized (Sein et al. 2011)—in the best possible way the *situated nature* of research it allows, so that a broader learning and reflection is possible. Such a deliberation about generalized outcomes should ideally comprise both a technical perspective (i.e. what was learned in terms of enhancing the design of the artifact → design principles) and a social perspective (i.e. what was learned regarding the context of use and the user him/herself → rich, contextualized descriptions about user behavior). However, in collecting and presenting the research findings, ADR is different from DSR as it favors authenticity over controlled settings (and thus evaluation is not presumed to be separable from designing as assumed in traditional stage-gate DSR models), and different from AR as it puts more emphasis on an artificial solution of the problem.

A second commonality of the mentioned approaches is the overall goal to produce *useful* research. This is primarily *not* determined by the researcher but by the affected person or user of the proposed solution. In this sense, an understanding of the context of research is crucial (Iivari 2003) and helps to better understand both the problem, the specific design decisions during the iterative/participatory design process, as well as the added-value the proposed solution delivers to the target group of the research endeavor. Consequentially, in the next section we provide a brief overview of the context of our study.

Situated problem and ecosystem description: Why are existing monitoring solutions not used?

As mentioned earlier, with this paper we seek to show that an ADR-inspired approach to social innovation could be a useful alternative to large-scale, industrial focused research in the area of AT. However, innovation does not happen in a vacuum (Gardien et al. 2014), but is embedded in an ecosystem where competing demands, competing solutions, and differing constructions of the problem exist. We expand on these aspects below.

Situated problem description and design goals

For more than a decade, local governments and the European Commission have invested considerable amounts of financial resources into experimentation with AT for elderly with the goal to increase autonomy of elderly people so that they can stay longer at home (Kubitschke et al. 2010). This has not been an end in itself. Much evidence points into the direction that elderly people residing in a homecare setting are much more independent and active (Mageroski et al. 2016; Sun et al. 2009) and economically more viable as if they would be treated in long-term care facilities (Wimo et al. 2010). However, this comes with the downside that they are much more liable to patient safety incidents (Tudor Car et al. 2017), which makes remote monitoring solutions particularly important for research.

Especially sensor-based systems for patient monitoring have gained great attention in the past years (Pantelopoulos and Bourbakis 2010). With the help of sensors and actuators integrated in clothing, shoes, bracelets, phones, watches, or integrated in smart home appliances, it is possible to constantly track and accumulate a huge amount of biological, physical, behavioral, or environmental information (Swan 2013), which—if deliberately combined and designed with foresight—can be purposefully used to improve the quality of life of elderly people (Mileo et al. 2008). Also from an economic perspective, such integrated sensor networks may be largely beneficial as they have the potential to relieve the pressure of health and care institutions by reducing the number of onsite visits or even stationary treatments (Baker et al. 2007).

Yet, there seems little indication that the traditional demarcation lines between clinically oriented systems and more patient-centered environments have been overcome by large-scale policy-driven projects (Mettler and Raptis 2012). Today's solutions for remote home monitoring of elderly people, and *dementia* *patients in particular*, frequently do not reflect their actual needs (rather emphasizing the needs of physicians or health insurances and not necessarily the needs of patients, family members, and caregivers) (Karunanithi 2007), are rather complex (as they need to fulfil a high reliability design in order to get FDA or CE approved) (Hamel et al. 2014), are rather expensive easily costing thousands of dollars (as there is a strong commercial motive) (Chan et al. 2008), and frequently use proprietary standards so that an integration of other components is not always possible (as there is an intention to create lock-in effects).

Hence, despite the rapid technological progress manifested by a greater availability of broadband networks, increased miniaturization, and cheaper microchips and sensors and even though the number of elderly people in need of support is constantly increasing, the widespread use of remote monitoring solutions has been limited (Khosravia and Ghapanchia 2016)—even in relatively wealthy countries. In view that dementia is affecting ever more people, causing massive social distress and great economic losses—around $236 billion each year in the U.S. only (Alzheimer's Association 2017)—we chose to take an alternative approach that we will delineate in the next sub-section and that fulfills the subsequent design goals:

- *Simplicity over functionality*: Our solution should address the basic needs of remote monitoring and be easily understandable to elderly people, their family members, and caregivers. Accordingly, we refrain from using complex setup routines or high reliability designs in order to keep the solution as effortless and usable as possible. However, this comes with the potential disadvantage of having less options for modification and adaptation of the solution as well as a higher tendency of errors (e.g. false alarms).
- *Reuse over innovation*: To minimize development costs, time-to-market, as well as to increase the chance that our remote monitoring system is affordable for elderly people, we chose to reuse existing, low-cost components instead of developing sophisticated, high-priced, custom-made hardware and software. The downside of this design decision may be less "appealing" or more "clumsy" devices and user interfaces.
- *Connectivity over security*: Finally, our solution should use open technology instead of proprietary standards so that—if needed—it can be adapted to fulfill additional requirements and be easily integrated within a smart home environment and the personal communication infrastructure of involved people. In relying in open standards our solution may become more vulnerable as we are dependable on others that security protocols are kept up-to-date on a regular basis.

To summarize, whilst quite a number of top-down funded, "civic" pilots and trials exist that aim at building more sophisticated solutions, our project is different in that we use a grassroots-like approach (Eliasoph 2009) intended to develop a light-weight, low-cost, and open solution that reasonably computer literate family members, caregivers, or even elderly can install and maintain by themselves. There are other low-cost health monitoring appliances, addressing a similar problem as we do (e.g. Felisberto et al. 2014). Following the rationale proposed by Järvinen (2007b), we therefore would classify our findings not as completely novel design, but as a proposition with an alternative goal function and another approach to building and evaluating, and contextualizing its outcomes.

Ecosystem

In developing our solution, we can count on a broad ecosystem of different stakeholders with varying roles and activities throughout the ADR process (see Figure 3), as we articulate next. We chose an *IT-dominant building, intervention, and evaluation logic*, as described by Sein et al. (2011). This means that our initial focus was on developing different versions of artifacts and then improve selected design variants by continuously instantiating and repeatedly testing assumptions, expectations, and knowledge about and with users and their use environment. We thus applied participatory ADR practices, as discussed by Haj-Bolouri et al. (2016), to guide our reflection and learning about the developed artifact and its implementation into elderly homes.

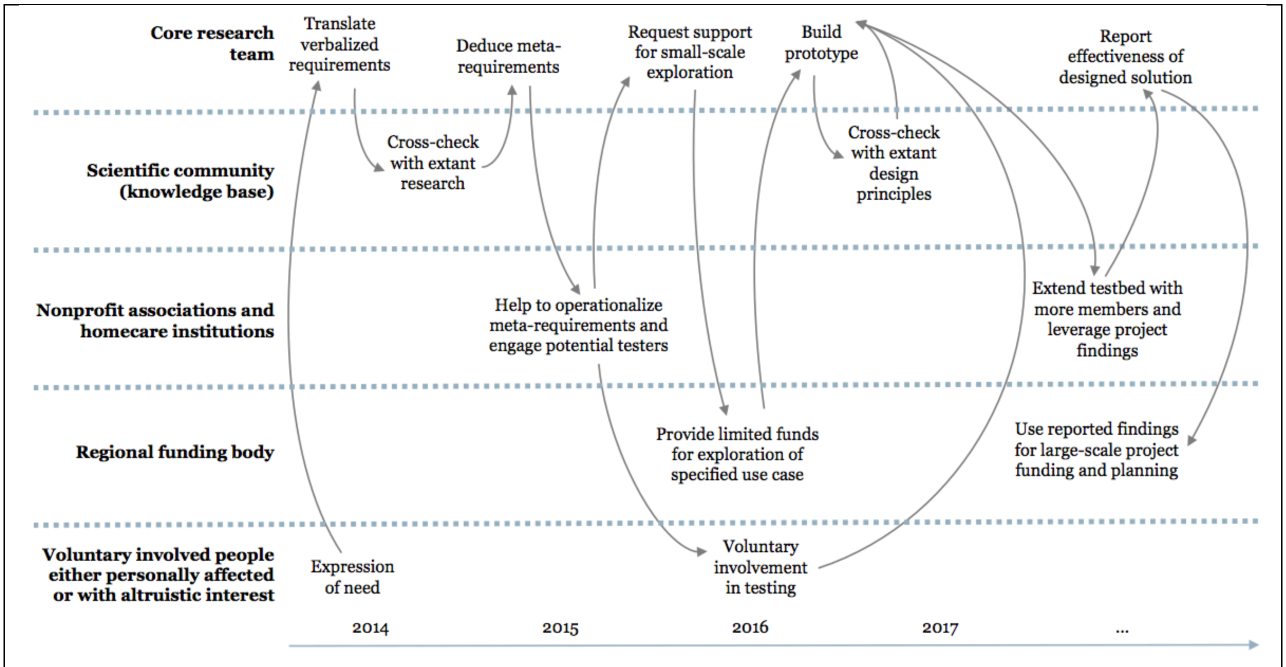

Figure 3. Stakeholders and different steps in our project

As with many design-oriented studies (Purao 2002), we started this project in 2014 with a certain expression of need to overcome the previously issue regarding the fact that existing remote monitoring solutions for elderly people are not easily accessible because of the mentioned reasons. The core research team consisted of a group of four researchers with different disciplinary backgrounds (spanning from social sciences to computer science) and working in different research institutions. Two of the researchers had a family member who required increased care and support. Consequently, and personally motivated to address this issue, we initially translated the verbalized exigencies of family members and caregivers into an initial list of basic requirements.

With this list in hand, we searched the knowledge base for best practices, design principles, and other recommendations by conducting a scoping review, as defined by Grant and Booth (2009) and which we will describe in the next section. Building upon the gathered requirements and evidence from the knowledge base, we deduced a number of meta-requirements with which we confronted some regional nonprofit associations, homecare institutions, and other colleagues in lively presentations and discussions. These activities helped us later on to recruit interested homecare organizations and senior citizens for testing the various versions of the developed prototype and, as in other occasions (Martin et al. 2013; Meiland et al. 2014; Robinson et al. 2009), improved the overall design of the solutions.

In 2015, we decided to intensify our activities by applying for a small budget at a regional funding body. On the one hand, this helped us to partially move away from a garage-based development environment towards a more individually regulated situation where we could also spend some working time for further exploring and refining the solution in our research institutions. On the other hand, it gave us a little leeway to purchase additional hardware so that we could start tests in the laboratory but also in the field with real patients. This allowed us to extend our testbed and increase our outreach of the developed measures. Nevertheless, other than in large-scale project setup, resources were still limited due to the fact that regional funds were only available in retrospect (i.e. after providing a clear proof for what the tax money was spent and what we achieved with it). Yet, our findings served the funding body as basis for establishing a supra-regional ambient assisted living lab with the intention to harness and leverage the results of several grassroots-like projects for the community within and across the region.

We expand on the different components of our remote monitoring solution in the next section.

The *iCare* Bot: Designing the low-cost monitoring system

Herbert Simon et al. (1987) characterized the process of problem solving by means of three activities. First, an *intelligence* activity where the problem finding or problem recognition happens (which is typically characterized by a more or less structured search for information concerning the problem and existing solutions). Second, a *design* activity where the development of alternative solutions is performed and lastly a *choice* activity, where the alternatives are evaluated in order to find the best option. As described by Sein et al. (2011), these last two activities are particularly hard to entangle when conducting ADR. Hence, in this section we will limit ourselves in describing (i) the meta-requirements which we identified in the knowledge base and discussed and agreed upon with representatives of nonprofit associations and affected people, and (ii) the latest version of our remote monitoring solution which we extensively tested in a laboratory environment and which we are currently evaluating in the field with elderly people and homecare institutions.

Meta-requirements

The body of literature regarding AT is vast due the fact that many different connotations and meanings coexist. For instance, Marshall (2000) defined it as "[…] *any item*, piece of equipment, product or system, whether acquired commercially, off-the-shelf, modified or customized, that is used to increase, maintain or improve functional capabilities of individuals with cognitive, physical or communication disabilities." Gibson et al. (2014) point to the fact that AT does *not only refer to electronic equipment*, but also quite simple devices such as calendar clocks, as long as they provide assistance with activities of daily living or promote activity and enjoyment. Accordingly, to identify existing design principles for IT-based solutions as well as to verify and possibly extend our initial list of requirements, we chose to conduct a *scoping review* of the literature using `"Alzheimer" OR "Dementia" OR "mild cognitive impairment" OR "amnesic"` as keywords to characterize our target group together with `"information technology" OR "information system" OR "assistance system" OR "assistive system" OR "independent living"` to determine the nature of the solution space. We performed our search in disciplinary (e.g. ACM, EMBASE, PsycInfo) as well as cross-disciplinary databases (e.g. EBCSO, Web of Science) and obtained, as of July 2015, a total of 874 articles were found. After discarding duplicates (335) and articles with irrelevant content (421) we ended up with a final list of 118 articles (papers were judged to be relevant when their abstracts indicated that the study gave insights into current AT prototypes or evaluations; in case a judgment regarding the relevance of an article was not possible on the basis of the paper's abstract, we read the introduction, the discussion, and the conclusion section in order to decide whether to include it or not).

To derive meta-requirements, out of which the most important ones are shown in the subsequent Table 1, we used a stylized facts approach for analyzing the remaining articles (Houy et al. 2015). Besides getting a more profound understanding on the existing design knowledge for *building* our solution, we also found a couple of interesting anecdotes and surprising findings concerning some tensions and trade-offs from *using* such a system. For instance, White and Montgomery (2014) reported that both, elderly people and their caregivers would prioritize safety over privacy. Similarly, McCabe and Innes (2013) mentioned that elderly people appeared to be less concerned with ethical issues, which could emerge from a constant tracking and supervision of their activities, but rather with the way how AT could be integrated as safety precaution in their living environment (e.g. when broadband network access is not available or computer literacy among family members and caregivers is low). Lastly, some articles pointed to the fact that monitoring solutions—even when purposefully designed—may be more useful for dedicated users, such as senior citizens aged between 75 and 84 (hence, well passed the middle-age but not too old to be physically inactive) or who have rather moderate than mild or severe dementia (Pilotto et al. 2011).

The insights obtained from the scoping review together with the narratives from personal discussions with affected people, nonprofit associations, and colleagues in the field of HIT guided our further design and choice activities, which we will delineate in the next sub-section.

Table 1. Most important identified problems with corresponding meta-requirements and resolution strategies

Identified problem	*Meta-requirement*	*Possible problem resolution*
Not considering the needs of family members and caregivers → this potentially increases the need for training and diminishes the chance that the care environment of the elderly person promotes and supports the solution (Olsson et al. 2012)	Inclusive design for affected person and his/her care environment	Perceiving family members and caregivers as (possibly the only) user of the system
Wanting to address to many day-to-day issues and to be too innovative → this increases complexity and diminishes the possibility of a solution at reasonable cost (Mao et al. 2015)	Lean design of software and reuse of existing hardware components	Using standard hardware and software to reduce costs and increase integration with existing environment
Wanting to collect as much data as possible → this increases the chance of using a lot of sensors, limiting an elderly person in their mobility and potentially causing a stigmatization (Lotfi et al. 2012; Robinson et al. 2009)	Focus on non-intrusiveness of the hardware	Using only a few, standard hardware components, which can easily be arranged in the rooms of an elderly person
Wanting to visualize all the collected sensor data → this increases the chance of an information overflow for the person who receives alert messages (Evans et al. 2011; Meiland et al. 2014)	Clean and understandable presentation of relevant information	Limiting activity reports and alert messaging to a minimum
Not considering the infrastructure that already exists → this diminishes the ease-of-use of the solution and increases the chance of duplicated or unused hardware and software (Mao et al. 2015)	Integrative and open design of software and hardware	Using a user interface that is already known by the people involved in the care of the elderly person

The iCare Bot

To achieve our formulated design goals and considering the identified meta-requirements for a purposeful design of a remote monitoring system for elderly people, we experimented with a series of different hardware/software alternatives. We finally opted for a *Raspberry Pi* based system—a $40 minicomputer of the size of a credit card running a Debian-based operating system—as the hardware has proven to be sufficiently reliable for smart home applications (Jain et al. 2014), offers a good value for money (Duarte et al. 2016), and can easily be extended with specific onboard accessories and any other standard, off-the-shelf component (e.g. web cams, motion sensors, navigation modules, displays etc.).

The *iCare Bot*, as we named our remote monitoring solution, consists of a Raspberry Pi 3 minicomputer with on-board WiFi, USB port, Bluetooth and Ethernet, protected by a simple case made out of plastic (see Figure 4). This box (around 8cm respectively 3 inches in length and width) can be positioned anywhere in the home of an elderly person if there is a power supply nearby. As there is the chance that an elderly person accidently unplugs the *iCare Bot*, we additionally incorporated an uninterruptible power supply (UPS) module which delivers enough electricity to safely shut down the equipment and to inform family members and caregivers by means of an alert message, given that a deactivation or device failure could have severe consequences concerning the safety of the affected person (Boger and Mihailidis 2011).

For motion detection (e.g. to find out if an elderly person is awake or wandering around at nights), we use a $40 battery-operated wireless sensor with an ultra-low power consumption and which can be placed anywhere in the room of the elderly person. This sensor can be programmed individually, for example, for having a scheduled activation/deactivation (e.g. to be turned on only at night-time). This allows us to trigger alert messages for different use cases, such as sending a message to family members and caregivers in case there is no activity in the morning or when an elderly person leaves home during the night. To get a kind of "proof" that this really happened, we use a web cam—costing around $20—which shoots a photo or short video triggered by a sensor event or upon request.

The basic configuration of the *iCare Bot* is easily expandable by additional motion sensors, web cams, or other peripherals as it uses an open standard for connecting all the devices.

Figure 4. Hardware used for the remote monitoring solution

As user interface for displaying alert messages in various formats (e.g. text, pictures, videos) as well as a means for easily connecting all involved parties of a complex care setting (e.g. wife/husband, children, caregivers, neighbors, or other relatives), we use the cloud-based instant messaging service *Telegram Messenger* (see Figure 5). We opted for this solution as it allows for end-to-end encrypted messaging, is open-source (providing an extensive API for creating programs), does not restrict the size of messages (so that longer videos can be transmitted), runs on most common platforms (i.e. PC, Mac, Linux, iOS, Android, Windows Phone, and Ubuntu Touch), and does not incur any costs for usage. Moreover, *Telegram Messenger* provides the possibility to create chatbots—computer programs that facilitate a human-machine dialog by means of natural spoken language (Klüwer 2011) and serve as interface for triggering certain code (e.g. by scanning for keywords within the messages). Such chatbots have already been purposefully used in a variety of use cases in outpatient medicine and social care for senior citizens (Abashev et al. 2016; Atay et al. 2016; Tokunaga et al. 2017).

In our case, we use a chatbot mainly for the purpose of user management and configuration; for example, instead of a complex registration procedure, we can add a person into the group of alert recipients by simply sending a message to the chatbot (using a specific keyword). The owner of the *iCare Bot* can then accept or reject this request and thus actively administer the inner and outer circle of his/her care environment (see Figure 5). Other tasks, such as turning alert messages on or off, can also be triggered by simply sending a text message to the chatbot.

Because other instant messaging services enjoy a greater popularity (e.g. local homecare workers frequently use *What's app* for self-organization and communication), we are in the process of extending the support of other applications. However, this is made difficult since not all messaging services provide an accessible API or chatbot functionality, which is needed to secure a similar user experience (in terms of simplicity, but also in terms of royalties and charges).

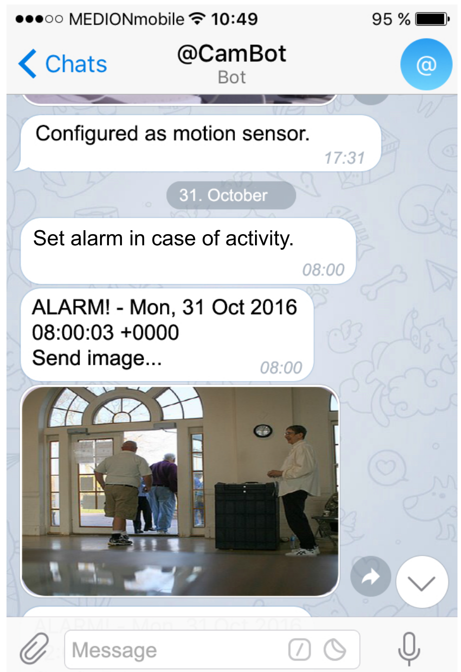

Figure 5. Exemplary alert message using the Telegram Messenger

The *iCare Bot* can be deployed to fulfil several use cases. For instance, it can be used to monitor suspicious activity of elderly, particularly because wandering is a frequent behavioral disorder in dementia patients. The term "wandering" thereby refers to seemingly aimless or disoriented ambulation throughout a facility, often with observable patterns such as lapping, pacing, or random ambulation (Carr et al. 2010). Particularly at nights this could be dangerous, because the elderly person could leave home without being noticed by family members or caregivers. In order that this does not happen, the *iCare Bot* could be set to report any nocturnal movement (as it is equipped with a night vision camera) by sending an alert message. During day-time, the *iCare Bot* can be used for analyzing overall activity of a person. If there is no movement after a certain interval, it could trigger an alert message which informs caregivers of a possible critical incident, such as a possible disappearance of the elderly or other serious adverse events, such a cardiac arrest or stroke.

In the next section, we describe our key learnings from the development and tests we run in a laboratory environment as well as preliminary findings from field tests.

Key learnings: What did we learn so far

As mentioned earlier, performing research using ADR requires intensive and repetitive interaction with—in many cases—a broad or greatly enmeshed and involved research ecosystem. In developing and testing our solution, we have conducted distinct activities to obtain user feedback and to test our design hypotheses, such as for example site visits and local experiments in homecare institutions, interviews with affected people and caregivers, or public talks in order to demonstrate and discuss the form and functioning of the prototype. Moreover, we have run extensive tests in a lab environment for evaluating the technical accuracy and reliability of the implemented motion sensors and cameras at our research institutions. As simple, cross-sectional acceptance test would not provide substantial evidence concerning long-term use issues, we will further conduct a longitudinal field study at the private home of an elderly couple as well as at the premises of a homecare organization in order to evaluate the installation procedure, configuration, and day-to-day handling of the *iCare Bot* in the real use environment and with real users. This is done because long-term engagement and distrust has been identified as a major problem, frequently resulting in individuals abandoning the use of such systems without garnering meaningful outcomes.

It is important to notice, once more, that ADR is an *iterative process* that is refined over repeated cycles of inquiry. To our view, not only reflection and learning about the last design iteration or “final artifact” is noteworthy. Each cycle can and should produce relevant findings concerning the design and implementation into practice. A timely communication of such findings could be decisive for other projects.

Building upon a rich set of experiences from the first 3 years of the project, we will hence articulate our current design-related learnings (i.e. a reflection of the findings we uncovered regarding the design choices we made during the development of the *iCareBot*) and contextual learnings (i.e. a contemplation of what we found out from conducting our grassroots project in the AT domain with limited funding and motivated by civic actions in our situated context).

Design-related learnings

Looking back to our formulated design goals and meta-requirements (see Table 1), we have to remark that achieving an integrative and open design of software and hardware without jeopardizing simplicity and ease-of-use posed a major challenge. While the connection and detection of the peripherals (e.g. web cams, motion sensors) with the Debian-based operating system of the Raspberry Pi was unproblematic, a wider opening of the architecture of the *iCare Bo*t, so that it can easily be integrated in a smart home environment with other components, presented a major difficulty. Although open standards for home automation, like *openHAB* (openHAB Foundation 2017) or *FHEM* (FHEM Association 2017), are available, the configuration of such platforms are not self-explanatory, hence, not really usable for a care environment where family members and caregivers are pressed for time or suffer from stress (Boots et al. 2016; Torti Jr et al. 2004). For that reason and although we deem it important to amplify the connectivity of our solution (as it would allow us to explore a greater variety of use cases), we have chosen not to facilitate any configuration options for users. Nevertheless, because of the simplicity and comprehensibility of the capabilities of the *iCare Bot*, health professionals and non-professionals alike demonstrated a high level of interest for using our solution. We explain this positive attention received by the fact that extant solutions providing a similar functionality usually require a complex setup procedure and extensive training (Evans et al. 2011), while ours—although extremely limited in functionality—does not need a complicated installation and uses an instant messaging service as user interface, which functioning is well-known by most of the involved people (e.g. because they already use instant messaging for leisure and business). A similar observation was made by Robinson et al. (2009), who reported that it was of utmost importance to caregivers that digital devices can be easily integrated into their daily routines. In this sense, a generalized finding would be to emphasize task integration over infrastructure integration when designing AT.

Another challenge presented the design of an efficient and non-intrusive device, which is robust, affordable, and visually appealing all at the same time. Whereas first versions of our prototype had motion sensors and camera integrated in the case of the *iCare Bot*, we opted for a design with external peripherals because it improved the sensing perimeter and the quality of images given that motion sensors and web cams could be placed anywhere in the room (i.e. not necessarily nearby a power supply). This design choice substantially increased accuracy and reliability of our solution, however, with the cost of a less engaging design. Although earlier studies reported that the latter is extremely important in view of acceptance of the solution (McCabe and Innes 2013), we found that the involved people rated accuracy and reliability higher than engagement. Accordingly, we would posit—at least for the use case of remote home monitoring of elderly people—that a non-intrusive design is less important than a design that is more reliable and efficient in terms of safety precaution.

In terms of the frequency, format, and type of alert messages we have no conclusive results yet. Several studies, which we identified during the scoping review, suggest that an adapted and personalized delivery of information is crucial (Boger and Mihailidis 2011; Ghorbel et al. 2013). However, providing contextualized and situated notifications would demand for a more elaborate configuration, including the storage of personal settings and data, which not all users feel comfortable with. Moreover, this could peril the current simplicity how users interact with the system (i.e. sending a text message with a specific keyword to the chatbot to invoke some actions). While we could extend the configuration options of the *iCare Bot* by adding some more instructions upon the chatbot reacts, we would—at the same time—require the users to invest more time into learning and remembering new keywords (currently only a handful of them, if at all, are needed to use the *iCare Bot*). Until now, we do not know how to solve this trade-off between adaptability and simplicity and therefore need further tests to determine the significance of personalized notifications.

Contextual learnings

When reflecting on the course of the project, we can point out that using ADR as approach to social innovation was highly beneficial within our research ecosystem. Other than existing studies, which reported difficulties in recruiting and working with affected people (Boger and Mihailidis 2011; Meiland et al. 2014), we did not encounter any problems in finding nonprofit organizations, homecare institutions, or private households of senior citizens for collaboration in the project. On the contrary, we had rather the problem of not being able to attend to all public events we were invited to. This continuous effort to disseminate and discuss our research findings in society (together with the relatively small size of the core research team) came with the drawback of a slow technical advancement though. On that account, we would stress the fact that a dialog with and inclusion of the public is helpful in reaffirming design hypotheses, yet it is exceedingly time-consuming and exertive as other studies corroborate (Bossen et al. 2016; Grönvall and Kyng 2013). Therefore, a proper consideration is required whether a fast time-to-market is more important for the research team (e.g. to keep motivation high or to ease the personal situation) or a broader incorporation of the research ecosystem (e.g. to establish new contacts for broadening the testbed of the prototype).

A faster progression of the project is also dependent on available funding. Other than in large-scale, policy-driven innovation initiatives, our project operated with limited financial backing, which is made available in retrospect by the regional funding body after providing a clear statement regarding the value-for-money. This forced a more out-of-the-box thinking and iterative approach, as we could not afford large pre-investments. In that we focused on a lean design of the software and reuse of existing hardware, having to operate with limited resources was not an issue though. Nonetheless, there might be social innovation initiatives and projects which presumably may require high investments upfront. In our case, having a clear understanding of the situated problem early in the project genuinely helped to avoid misspending. Also coercing ourselves to thinking in step-wise, simple approximations instead of addressing the entire problem with one giant solution kept our demand for resources low. However, this again comes with a downside. Grassroots-like projects heavily rely on voluntary associations, informal community groups or engaged citizens, who have certain expectations (Mulgan 2006). Particularly when it comes to the cure and care of patients, these expectations are relatively high (Cimperman et al. 2016; Hirani et al. 2014), as people are suffering or are in real need for a quick solution of their issues. Accordingly, providing only incremental support for their situation can sometimes be unsatisfactory. For the purpose of successful relationship building and for preventing disappointment and frustration of involved stakeholders, it is therefore of utmost importance to establish a convincing expectation management early in the project. Since public opinion is crucial for substantiating the value-for-money, this has not been an end in itself regarding a project setup like ours.

A continuous exchange with affected people also helped us to refute initial concerns regarding the desirability and social approval of remote monitoring. Despite there is a heated discussion in the extant literature about ethical and moral implications from using AT (Chung et al. 2016; Eccles et al. 2013; Fisk and Rudel 2013), we were not confronted with this issue in our project so far. We explain this lack of interest in engaging into this debate on the part of local authorities, nonprofit organizations, and senior citizens by the strong need for a reliable and affordable solution. Our observations therefore confirm previous studies (McCabe and Innes 2013; White and Montgomery 2014), which found that senior citizens and caregivers favored safety over privacy. With this, we do not posit to forget about ethical principles in designing AT. Unnecessary data collection or data repurposing—specially in healthcare (Collmann et al. 2016; Mittelstadt and Floridi 2016)—present a major problem nowadays.

Moreover, although effective safety precaution is most appreciated by senior citizens, there should be still a priority to minimizing security threads. Several recent cases have shown the dark side of technology, as many solutions are insufficiently protected and could therefore be misused for harmful purposes like identity theft or cyberstalking (Institute for Critical Infrastructure Technology 2016; Markus 2015). In this sense, there is a fine line to balance between maximizing value for the affected people in the short-term and protecting them from severe risks in the long-term. We found that this could be an eminent issue in grassroots-like projects as comparison to large-scale, policy-driven initiatives which are keener to deliver high reliability designs because of an intended FDA or CE approval.

Concluding remarks: The path yet to go…

Is there a place for social innovation on the agenda of public decision makers for addressing the current challenges in health and social care? In line with extant research (Rotmans et al. 2001; Sengers et al. 2016), we argue that small-scale projects based on civic actions can play a role in bringing about positive change in a stepwise manner and should therefore be considered as valuable complement to large-scale, policy-driven initiatives.

While the results of this project only address a tiny portion of the overall challenge, we nevertheless show that it is a good way to go forward. Other than large-scale, policy-driven initiatives that envision an ambitious, but extremely risky "grand design" to obtain public funding (Lippeveld and Sapirie 2000), grassroots-like projects bear less risk and are—in most instances—better rooted in society, which is of utmost importance to develop responsive and purposive solutions. Moreover, the value of small-scale but directed initiatives is commonly easier to explicate than for very innovative, complex projects (Male et al. 2007; McKee et al. 2006). This might be particularly important in a regional context, like in our case, where citizens are usually more eager to know how tax money is spent.

In planning and conducting our project, we found an ADR-inspired approach to social innovation much useful. However, while it is a convenient paradigm for problem- and people-oriented research in healthcare (Sherer 2014), it lacks some well-defined and widely accepted standards for presenting the outcome of research. Despite the effort of some scholars in advancing in this regard (Papas et al. 2012; Sein et al. 2011), we still faced problems in convincingly presenting our findings because existing guidelines are not exhaustive or detailed enough in comparison to the methodological standards of behavioral IS research. Although this has not been the primary focus of this study, it could represent an exciting avenue for future research. In addition, it could be interesting to further investigate the transformative possibilities of ADR in projects that are based on civic actions.

In terms of our artifact, we also see a long path ahead of us. Certainly, first tests in the lab environment and with selected users leave us optimistic. However, we still need to extend our testbed and further evaluate the prototype in practice. We will do so by running a longitudinal field experiment in a household of an elderly couple as well as in one of our voluntary homecare institutions. With this, we hope to get richer insights as typical (cross-sectional) acceptance tests, which do not allow for identifying workarounds or other unforeseen ways (Alter 2014; Ferneley and Sobreperez 2006) how senior citizens will interact with our solution (e.g. using the *iCare Bot* as communication device to keep in touch with their children and caregivers).

Finally, we also seek to motivate IS scholars to try community-engaged research—in one form or another. The list of technological and social issues and challenges remains very long indeed (Becker et al. 2015). Bottom-up, grassroots-like projects could be a channel for exploring new ideas in a real-world setting with actual users. While it is surely a more time-consuming way to perform research, it is more satisfactory and enjoyable than pure lab research.

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