

# **LEARNING FROM A DESIGN EXPERIENCE: CONTINUOUS USER INVOLVEMENT IN DEVELOPMENT OF AGING-IN-PLACE SOLUTION FOR OLDER ADULTS**

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## **ABSTRACT**

Involving users during product development has been discussed as an important approach to user-centered design, in particular to avoid overemphasis on using “technology for technology’s sake”. This paper presents a case study of the user-driven processes and methods involved in a product development research project, the e-Home for Seniors study. The case study maps the development activities to phases of a generic product development framework. The specific methods of continuous interaction with users, research experiences, and team characteristics are examined in detail, as well as mechanisms to allow user input to be easily incorporated throughout the development cycle. Insights for development of products targeted at older adults, many also relevant to the general population, are discussed to inform researchers and practitioners.

*Keywords: design methods, new product development, user centered design, design for aging population, field study*

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## **1 INTRODUCTION**

User-centered design and user involvement in design have been popular topics in product development. However, while many products for the general population have employed user participation methods in their development, they have not yet been widely applied to products targeted at older adults.

In this paper, a case study approach is used to describe product development activities, in the context where the target segment is older adults. With an examination of the process, methods, dynamics and decisions in an example case, implications for research and practice can be generated. A case study can serve as a learning tool where real stories are analyzed for general insights (Flyvbjerg, 2006).

This paper describes the e-Home for Seniors study on the development of a socially connected medication management system. As a research project, the e-Home system was planned, designed, developed and tested with various methods of user studies and user involvement. In this paper, a retrospective description of the objectives, methods and results of user involvement throughout the design process is presented. The specific methods and insights are described in relation to the iterative stages of development. Also, a set of general lessons and implications for design of technology-enabled products for older adults and other special populations are discussed.

## **2 USER-CENTERED PRODUCT DEVELOPMENT METHODS**

In practice, a structured sequence of development activities, or a staged framework of development, is often followed for an efficient and effective development of quality products. One important activity carried out in the earlier phases of development is identifying customer needs. For this, a number of different methods of user studies, or activities done with the aim of understanding and extracting user characteristics and requirements, are used. This section gives a brief summary of literature on existing models of product development process, as well as an overview of methods used for assessment of user requirements. In addition, the topic of developing products for older adults, including the different characteristics that need to be addressed in development, is discussed.

### **2.1 Involving users in product development**

In many different domains and fields of study, the process of designing and developing products and services have been modeled and described. While the specific names and detailed activities varied by the different contexts, they usually go through the following generic process: the early stages where ideas and concepts are developed and finalized, the main design stages where the concept is realized into a product, and the later stages where the product is tested and manufactured (Ulrich and Eppinger, 2004; Magrab et al., 2009; Kaulio, 1998).

The early stages prior to product realization, often referred to as the fuzzy front-end, are where the product is defined and most strategic decisions and business plans are made (Kim and Wilemon, 2002; Alam, 2006). Previous studies have emphasized the importance of front-end activities in determining success of new products (Khurana and Rosenthal, 1998; Zhang and Doll, 2001). While various models differ in describing the specific stages, most of them put emphasis on identifying and assessing customer needs in the front-end (Bacon et al., 1994; Quinn, 1985; Khurana and Rosenthal, 1998).

Interactions with users in the early stages of development go beyond simple needs identification. Studies have found the importance of having users involved closely in design and development. Prior works have discussed that frequent and intimate user involvement is important for improving product concept, as well as for improving innovation capabilities and product market performances (Cooper and Kleinschmidt, 1987; Kim and Wilemon, 2002; Lilien et al., 2002).

### **2.2 Methods of user studies**

In the field of product design and development, various methods of user studies have been employed to generate ideas, identify needs, analyze use cases, and test prototypes and products. Popular methods include interview, focus group, scenario analysis, cognitive walkthrough, questionnaire, think aloud protocol, usage diary, user experiment, observation and physiological measures (Kujala, 2002; González et al. 2008; Courage and Baxter, 2005; Lee and Grogan, 2012; Mandryk et al. 2006; Pruitt and Grudin, 2003). The specific methods differ along a number of dimensions, including qualitative – quantitative, objective – subjective, user-driven – expert-driven, and performance-oriented – process-

oriented. For example, while the scenario method is usually expert-driven, qualitative and process-oriented, user experiment methods are often user-driven, quantitative and performance-oriented. Different methods of user studies can be carried out at different stages of product development. For example, focus groups can be done to generate concepts, and user experiments can be conducted later for prototype testing. It should also be noted, however, that a single method may be necessary at multiple stages. Software and web-based application may be able to benefit from using remote methods that may not require in-person contact with users (Hartson et al. 1996). Choosing the methods to use, and deciding when and how to carry them out largely depend on the nature of the product being developed, as well as the set of skills that the development team possesses.

### 2.3 Development of products for older users

Developed societies are already experiencing a rapid growth of older population. This demographic change is posing challenges to how products and services are developed. Older adults possess characteristics that differ from the general population. Due to changes in physical and cognitive capabilities, the form and interfaces of products need to be designed accordingly. Also, the previous experiences older adults have with technology differ from what younger people have experienced, and thus there exist differences in familiarity and anxiety with using new products.

The need to address the older population and their characteristics in product development has been recognized by academy and industry. However, products have often been developed based on an insufficient understanding or stereotypes of older adults. While older adults today are more connected, active and independent, biased social perceptions that view older adults as weak and unhealthy still exist. Studies have identified that there exists a lack of proper assessment on older adults' needs and expectations in product development, and that the experiential and cultural gaps between older users and younger developers are not being addressed (Eisma et al., 2004; Niemelä-Nyrhinen, 2007).

More effort is needed in investigating the topic of user-centered design and development for products targeted at older adults. Due to the differences in characteristics and experiences, questions may need to be differently phrased and one may need to go beyond simply asking. Because of potential biases, it may be dangerous to make assumptions and to employ purely expert-driven methods. To realize the potential value of such products, a discussion on how to effectively use and adapt various user studies methods to correctly and comprehensively understand older adults' requirements is needed.

## 3 THE E-HOME CASE STUDY

The e-Home for Seniors study, carried out by the MIT (Massachusetts Institute of Technology) AgeLab in collaboration with NTT Japan, is an example of designing, prototyping and evaluating products targeted at meeting older users' needs. The e-Home study was conducted as a process where potential users were deeply involved in generating, designing, prototyping and evaluating an aging-in-place solution. The user participation approach was employed to minimize the gap between designers and users by better translating the user inputs into product functions and design features.

The project began with an identification of multiple issues related to aging-in-place. Then, based on interactions with potential users, the concept of a home technology system with medication management and remote communication was selected. The system architecture and detailed features were designed through several iterations that involved evaluation of various technologies and alternative architectures. After prototyping the concept, the system was extensively tested in the laboratory and in the field with potential users. During the long-term field testing, multiple user studies methods were employed for a comprehensive analysis of interactions.

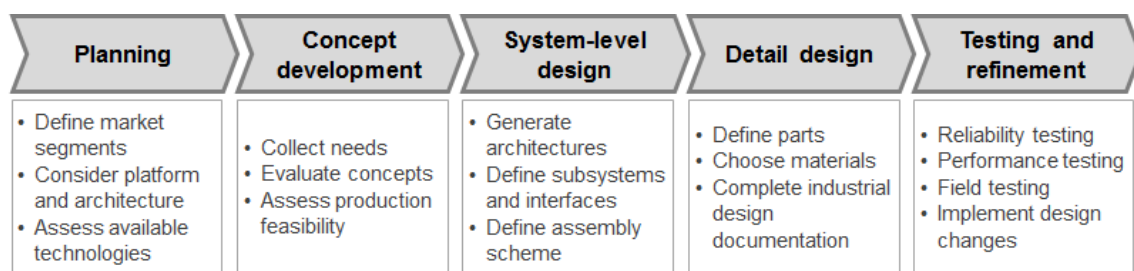


Figure 1. Case study framework (summarized from Ulrich and Eppinger, 2004)

The user-centered design principle and various related methods were employed early in the development process from the planning and concept development phase, as well as later during the iterative testing phase. In this section, we describe the specific requirements, methods, uncertainties and results as mapped on to the generic product development framework suggested by Ulrich and Eppinger (2004) as shown in Figure 1. The production ramp-up stage is excluded in the case study as the e-Home system was aimed at prototype development rather than a marketable system. The descriptions focus on how the users were involved, what insights were found, and how the user studies results were integrated into the overall design.

### **3.2.1 Planning**

The project started with an examination of the user segment. The assessment of general needs and expectations involved a careful survey of prior work. A considerable amount of work has been conducted in the domain to investigate the possibilities of developing solutions to improve the life of older adults. Two main issues were identified with respect to prior work. First, products designed to contribute to satisfaction of older adults have not been particularly successful in the market. Second, products proposed as useful in this area have not typically been reviewed to see if they contribute to adding to quality of life in an integrated way. That is, too often products or processes are proposed and evaluated in isolation while different needs and requirements may be closely related.

In many cases, older adults have reported consistently that they would prefer to age in place, that is, reside in own homes as long as possible without having to relocate. The ideal way to age in place would be to live longer confidently, comfortably and independently in locations and with people that they are familiar with. However, as they are often left alone to deal with life tasks on their own, they often face issues and problems related to isolation, mobility, hygiene, finances, health management, home management, safety, and nutrition. Furthermore, these issues are often interrelated. For example, problems with mobility can potentially worsen isolation issue, and failing to manage nutrition can lead to health issues. However, because previous studies focused on isolated point solutions, the breadth and complexity of aging-in-place issues have not been properly addressed.

The planning stage also involved an assessment of available technologies. An aim of the project was to create capabilities using accessible sophisticated technologies that could be used to develop features that could be integrated together. Since the project was run in collaboration with NTT Japan, a major telecommunications company, we had access to various telecommunications applications available. A variety of different sensors and identification technologies were surveyed as well since context awareness can provide benefits to aging in place. Through this process, we found a variety of off-the-shelf technologies, such as RFID and motion sensors, that were available at reasonable costs.

Based upon a preliminary research, the objectives of the project were outlined. The main objective was to design and develop a home solution that can assist in dealing issues related to aging-in-place. We decided to address multiple related issues and to involve older adults during the design process for a correct and comprehensive understanding. Also, for a quick and inexpensive prototyping, we sought to make use of component technologies that are readily available.

For project management, a rough schedule was outlined. The overall development was planned over one year, and a simple Gantt chart was first created to include major activities such as technology alternatives search, system design, detailed design, prototyping and testing in the unit of months. Also, while the project team initially included computer and mechanical engineers, an experienced project manager and a usability engineer were added as the project involved multiple issues and methods.

### **3.2.2 Concept development**

Preliminary qualitative research done at the MIT AgeLab on older adults' decisions on where to live has shown that a strong criterion was the ability to support social communication among family members and within a community. Continued discussions with the target users allowed us to create several use cases, or examples of situations at home, that could be improved through communication. These ranged from a remote caregiver desiring to communicate, communicating during meal time, to even making sure that a wastebasket is being emptied properly. Also, from two focus group discussions with older adults from age 55 and up, it was revealed that they greatly value a connected lifestyle with rich social interactions, as in the comment, "... people, it's like a gift!"

As the concept of family communication system started to emerge, we started looking at the other half of the user population, the children. A previous MIT AgeLab survey research had identified that adult

children, the informal caregivers, are very interested in knowing how their parents manage health, such as consuming and refilling medication (Coughlin et al., 2009). The importance of the medication compliance issue was confirmed with a literature review, as studies found non-compliance to be an extremely risky and costly, yet common, problem among older adults (Lee et al., 2011).

The strong user input and background information were used to prioritize and direct the goals of the e-Home project. We wanted our system to clearly demonstrate improved communication. As a way to facilitate the communication and assist remote caregiving, we decided on incorporating medication consumption management into the system. Thus, the final concept was defined as a home technology system for proactive medication management and enhanced communication.

The user studies had made it very clear that a parallel goal to that of communication was that of ease of use. The concept we considered had to be developed in such a way that it is pleasant to use, straightforward to learn, easy to install and manage, accurate and reliable. Lastly, we needed to ensure that issues related to privacy, which was also raised during the focus groups, were recognized and addressed, as older users may be uncomfortable with the monitoring function.

### 3.2.3 System-level design

The system-level design was driven by the requirements identified in the earlier stages of the project. An additional goal was to provide an architecture that provided flexibility to deal with any new requirements that came from issues related to implementation or from initial user testing. Another aspect of the architecture was the need to collect data on system usage as part of the research environment. This capability needed to make minimum demands on the users' network capability when used, and also maintain guaranteed privacy in the communications.

The system was designed with two main parts - medication management and remote communication - as stated in the concept description. At a functional level, four components - sensing, inferring, ruling and actuating - were defined. The sensing module is the interface to the real world and the sensors required. The inferring module stores data from the sensors and contains rules that define user events. It continuously matches incoming events against the rules and identifies user events. The ruling module analyzes user events, and identifies actions for users based on a set of rules. The actuating module is an output interface with the various components that the user sees (Asai et al., 2011).

Different configurations of RFIDs and motion sensors were tested for performance in detection of individual medications. Based on experiments, we decided to use an RFID system where the reader and the antenna are set in a perpendicular angle. The system also needed to detect if pills were actually consumed, which led to adding a precision scale to the system. For the communications module, a number of different options such as chat windows and phone connections were considered for direct contacts. After an evaluation of performance and use cases, we decided on using NTT's Meeting Plaza, which can operate as a one-click video chat program, and text messaging through the user terminal for delayed communication. For prototyping, we decided to use a regular all-in-one touchscreen PC for its flexibility, interoperability and usability. An information globe was added based on a use cases analysis, since users may want a quick-glance understanding of status when they are not close to the screen or when they have the screen turned off for privacy or cost reasons.

In short, the system design started from a simple structure as shown on the left in Figure 2. With a use cases analysis based on the user inputs from earlier stages, and with technology assessment and testing, the system design was specified as shown on the right in Figure 2.

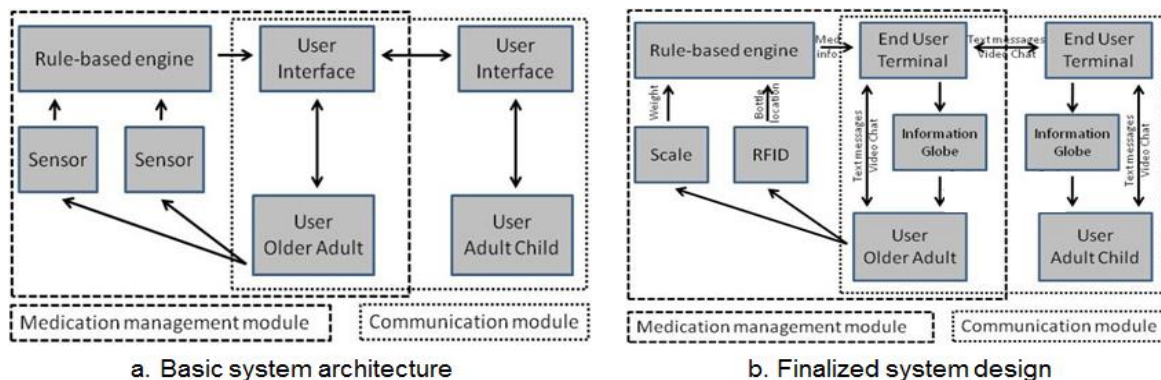


Figure 2. System architecture design (from Lee et al., 2011)

### **3.2.4 Detail design**

Part selection, software development, industrial design and interface design were carried out in the aim to meet the following requirements identified from the user studies in the concept development phase.

- The system should be easy to use: intuitive design, minimum user effort
- The system should be accurate: time keeping, medicine identification, weight measurement
- The system should be reliable: use of reliable Internet service, stable hardware connections
- The system should be easy to install: easy user manual, step-by-step wizard, USB connection

These requirements generally apply to any systems that involve user interactions. However, they were found to be especially important as it was revealed from user studies and literature that failure to meet these requirements can have critical outcomes, and that the target population is less likely to have various means of network connection and often less experienced with operating new hardware and computer applications.

The detail design of hardware, software engine and user interfaces were run in parallel. To facilitate efficient exchange of ideas, streamlined development and seamless integration, the main development researchers held daily informal meetings in addition to the weekly meetings that were already held. As specific tasks were defined, the overall project schedule was expanded to include detailed tasks, and was then redesigned using the units of weeks and days.

Through a market research and a technology assessment, several specific models were selected as candidate hardware components. They were evaluated on several dimensions including price, performance and features. One important principle we had during part selection, and the following design improvements, was that we should think about the integrated product rather than optimizing for the best part performance (Utterback et al., 2006). For example, the RFID parts were selected not in terms of the best detection power, but how they can be put together for the desired overall system behavior. Because the RFID system was to be used for short-range medication detection, we were specifically looking for an inexpensive and accurate system that didn't need to have the best performance in terms of distant detection. Based on such criteria, candidate models were tested and selected for system integration. This process of criteria setting, alternatives research and part selection with a focus on the integrated system was repeated for the precision scale and the computer as well.

For the development of the underlying engine and the software application, a set of functional requirements were first organized as a list that included adding and deleting medication to and from the database, detection and recording of medication bottle movements, detection and recording of bottle weight changes, keeping track of time, generating reminders and warning messages at scheduled times, sharing messages, and making calls through Meeting Plaza. The functional requirements were then organized and mapped onto a rough software component structure, which was then refined through iteration with unified modeling language (UML) and construction of system diagrams. After deciding on the detailed structure and flow, researchers with expertise in computer programming got involved in the detailed software development and coding. Several languages and tools were used, based in part on libraries that were available as interfaces to the hardware components that had been selected. Data transfers between the clients and server were encrypted to ensure privacy.

Making the system easy to use was the biggest concern as the user interfaces were designed. Through an examination of design metaphors, we settled on a corkboard interface. That is, the screen would show a virtual corkboard with reminders and notes pinned onto it. The corkboard metaphor was selected because it made the interactions natural and intuitive. It was also attractive because it could easily use touch as a user interface mechanism, as the need to support touch was folded into the specifications during part selection. With the interface, users were able to simply touch on a note icon to generate a note, touch and drag to move an existing note, and touch and drag the thumbtack to remove a note. The information globe, which was added as a redundant display component, had to easily show the system status even when the users are not close enough to the screen to read messages. With a consideration of human factors and general mental models, the globe was designed to alternate between colors red, green and blue according to system status. The colors corresponded to the colors displayed on the screen, and also to the common sense where red usually is used for warning.

The hardware, underlying engine and software application were then quickly integrated. An efficient integration was possible as the team continuously communicated at every stage of detail design. The interfaces among components were defined using simple mechanisms. For example, most of the hardware components were connected using USB cables, and the client software application was packaged as a general Windows application. The external components with the highest data

communication requirements were connected to USB connectors on the computer that were processed with the highest priority. The final prototype product is shown in Figure 3.

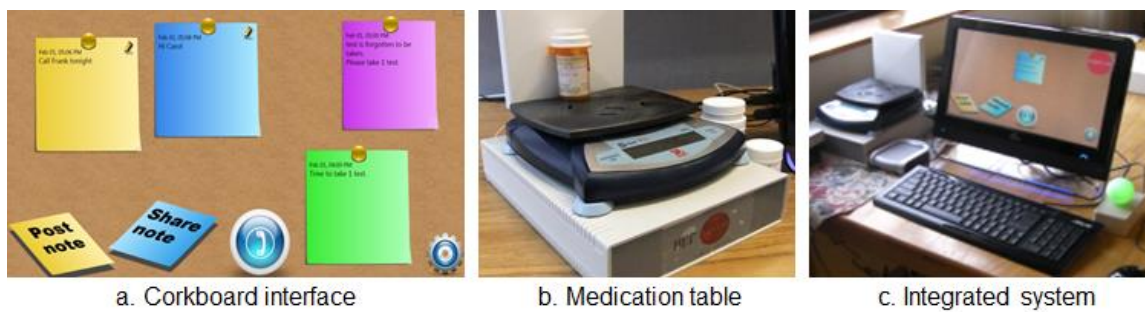


Figure 3. e-Home system

### 3.2.5 Testing and refinement

With an integrated prototype, a thorough laboratory testing was conducted to evaluate the system's functionality, reliability and usability under various use cases. Two systems were installed at MIT AgeLab to simulate an older adult and adult child pair. First, researchers used the system in a typical setting where the older adult would take medication a few times a day, and the both sides would occasionally exchanges calls or notes. This was done to see if the system was able to function as it was designed to. Then, based on prior interactions with potential users, a large number (over 30) of use cases were enumerated to describe the various purposes, components and processes with which users may use the system. Use cases related to possible failure modes were also described to test the reliability under different conditions such as unstable network connection. The researchers then tried the various situations described in the use cases to see if any design changes were necessary. A bug list was kept to record detailed results, which was circulated among the team.

The system was taken out for a short pilot field testing after incorporating the design changes identified from laboratory testing. The pilot testing was conducted with one older adult and her adult child in the Greater Boston area for a week in February 2011. During the week, the participants kept a diary of their interactions, problems experienced, and ideas for improvement. The pilot study identified several important suggestions, such as providing a one-page summary manual and the incorporation of audible announcement rings associated with newly arrived notes and communication requests. In general, the system was able to perform with no major problem in the field setting, and was well received by the two participants, as well as other family members at the adult child side.

The system architecture proved to be very flexible, and was able to easily incorporate inputs and comments received from users that arrived after the pilot implementation. After incorporating the design changes identified from the pilot study and testing the refined system for its performance and reliability, the system was put into the field. For the field testing, we recruited four older adult and adult child pairs through a screening process including an initial questionnaire and a phone interview. The older adult was required to be living alone and at least 60 years old. Both male and female participants were selected. To ensure that they use both modules of the system, an older adult and his or her adult child was required to be at least 25 miles or 40 minutes apart by driving distance. This was based on the reasoning that if they lived closer, they would be likely to communicate in person rather than use the system during the testing period. Also, the older adults were selected after screening out the candidates who were not on any medication at all and thus wouldn't use the medication module.

A long-term schedule of eight weeks was planned for understanding real-life usage rather than just getting results based on initial impressions. Over the course of eight weeks from mid-March to mid-May, 2011, the system alternated between two modes of operation. The two modes differed in the amount of information shared and the level of privacy that the older adults had. In the shared mode, medication notes were fully accessible to both older adult and adult child sides. In the local mode, however, only the older adult could view the medication notes. At the beginning, two pairs used the system in the shared mode, and the other two started using it in the local mode. They switched modes after the first three weeks, and all pairs were asked to choose a favored mode for the last two weeks.

During the eight-week period, the e-Home research team made four scheduled visits to each older adult home, and two scheduled visits to each adult child home. The visits were made for system installation, participant training, and collection of data. Visits were scheduled frequently and as evenly

as possible to maintain a close contact with the participants and to collect survey data at appropriate times. Additional visits were made for system repairs or additional training as requested. Participants also made contacts by phone or email to ask questions, report unexpected system behaviors, and to talk about any related matters.

Various topics were investigated with the field test. The topics, as listed below, concern the system's performance in real-life setting, potential user perceptions and attitudes, and ideas for future systems.

- How do users interact with the system? Do their interactions change over time?
- Do interaction patterns differ between older and younger, and between shared and local modes?
- How do users benefit from the two main modules – medication and communication?
- How do the two main modules interplay in the real-life setting?
- What problems do users experience with the system's performance and/or usability?
- What are potential ideas for the next generation of the system?

To investigate these issues in depth, several user studies methods were used at various times during the field testing. Multiple methods were used to collect both subjective and objective information, as well as both quantitative and qualitative data. The data collection methods are summarized in Table 1.

*Table 1. Field testing user studies methods*

Method	Time of collection	Data collected
Questionnaire	Four times, one at each scheduled visit	<ul style="list-style-type: none"> <li>· Information on system usage</li> <li>· User perception of the system</li> <li>· Perceived effect on medication compliance and communication</li> </ul>
System log (remote observation)	Throughout the eight-week period	<ul style="list-style-type: none"> <li>· Detailed usage of notes and video chat</li> <li>· Medication consumption information (time and errors)</li> <li>· Automatic daily transfer upon encryption</li> </ul>
Interview	At the last visit for about 30 minutes each	<ul style="list-style-type: none"> <li>· Feedback on system features</li> <li>· Perceived effect on medication compliance and communication</li> <li>· Ideas for future systems</li> </ul>
Usage diary	Throughout the eight-week period	<ul style="list-style-type: none"> <li>· System usage and errors</li> <li>· Ideas for improvement</li> </ul>

## **4 DISCUSSION & CONCLUSION**

### **4.1 Summary**

It is common, but unfortunate, that research activities, in particular activities that involve technology, can end up exploring areas that are driven more by the technologies than by a thorough understanding of customer needs. This paper traces the process and activities involved in the e-Home for Seniors project to explore and describe an example of how user-driven methods can be used in the development of products for older adults. The e-Home project was conceived from the beginning to identify, understand and address a major need of an aging population and their caregivers. Several processes to gather and prioritize user needs were employed at the beginning of the project to identify real needs, including direct and varied contact with target users. This emphasis on continuously using feedback was used throughout the specification process in order to select among alternatives as they came up. As ease of use was identified as a primary requirement, special emphasis was put on making the system inviting and easy to use. The architecture of the hardware and software was selected to allow changes in the system to be easily incorporated as the emerging system was reviewed with users. User inputs were also used create use cases, which then compiled into test plans to ensure that the product was reliable in the areas of most common use. The functionality of the product was checked repeatedly, including full use of preliminary system implementations and a pilot installation, the changes and improvements that were identified were easily incorporated. When necessary, more formal project management techniques were used to monitor and coordinate changes. The resulting product was enthusiastically received by users, used without difficulty by older adults often unfamiliar with technology, and was viewed by users as making a contribution to their lives and communication with family members. Several mechanisms were included to gather more detailed comments from users, which have successfully allowed a range of information to be collected for further work.



## 4.2 Implications

The e-Home study has several key implications and suggestions for future research in the domain of product development for older adults as listed below

- Make the system resilient: The needs and issues related to the older population are often complex, not clearly understood, and can rapidly change especially when health issues are involved. Developers and designers can often face unexpected feedback or problems that may require significant design changes. Thus, it is important to start with a flexible architecture that is resilient to changes in individual situations and needs.
- Leverage existing systems: It would be better to design products to be easily installed or added onto existing products, such as PCs or mobile phones which most of older adults already own, rather than building a separate system. This way, they can be made cheaper and more accessible.
- Examine relationships between needs as products are developed: While the specific field results are not included in this case study paper, we found that the communication and medication issues were deeply related in usage, creating a synergy effect. Sharing medication information acted as a trigger for communication, and communication played a role in motivating older adults to adhere to regimen. Such relationship may be found between other needs as well, and should be considered for system design as emergent behaviors can affect user experience.

The case study also has insights for product development in general. From mapping our experiences during to the generic framework, we were able to identify and highlight key lessons listed below.

- Iterate quickly and often: Many design iterations took place within a phase, and even across different phases, such as between testing and detail design. We found the iterative process to be helpful in improving system quality, functionality and usability in a short period of time.
- Make prototypes: We found it much easier to work with tangible prototypes rather than concepts and thoughts, especially since it is more difficult to conceptually analyze from older adults' perspectives due to inevitable gaps in understanding and experience.
- Get ideas from users: Rather than starting with a concept that we thought as important, we asked users to learn what they really wanted. This helped to have the system developed around previously neglected desire to communicate, rather than based on stereotypes of older adults.
- Maintain close contacts with users: From recruitment to wrap-up, field testing participants were in close and regular contact with the researchers for about four months. We found having them familiarized to the researchers helpful as it made them feel the process as less intrusive. This also facilitated in-depth conversations to close the knowledge and experience gaps.
- Have a flexible team: Rather than having a fixed set of roles, we found it much more effective to have an interdisciplinary team who assumed flexible responsibilities, because we were able to react quickly to different design problems and effectively manage user contacts.
- Keep shared documentations: During design and testing, we kept several documents that were shared within the team, including bug lists, meeting notes, field notes, and a schedule chart. We found that the documents served as an effective way of communication.

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