A METHOD FOR SUPPORTING DATA COLLECTION IN USER RESEARCH STUDIES AT DOMESTIC ENVIRONMENTS

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submitted by **AYDIN ÖZTOPRAK** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Industrial Design, Middle East Technical University** by,

Prof. Dr. Canan Özgen
Dean, Graduate School of **Natural and Applied Sciences** ____________________

Assoc. Prof Dr. Gülay Hasdoğan
Head of Department, **Industrial Design** ____________________

Assoc. Prof Dr. Çiğdem Erbuğ
Supervisor, **Industrial Design Dept., METU** ____________________

Examining Committee Members:

Assoc. Prof Dr. Gülay Hasdoğan
Industrial Design Dept., METU ____________________

Assoc. Prof Dr. Çiğdem Erbuğ
Industrial Design Dept., METU ____________________

Prof Dr. Tayyar Şen
Industrial Engineering Dept., Toros University ____________________

Assoc. Prof Dr. Mehmet Asatekin
Industrial Design Dept., Bahçeşehir University ____________________

Assist. Prof Dr. Çağla Doğan
Industrial Design Dept., METU ____________________

DATE:

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct. I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name :

Signature :

ABSTRACT

A METHOD FOR SUPPORTING DATA COLLECTION IN USER RESEARCH STUDIES AT DOMESTIC ENVIRONMENTS

Öztoprak, Aydın

Ph.D., Department of Industrial Design

Supervisor : Assoc. Prof. Dr. Çiğdem Erbuğ

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This thesis analyzes data collection tools and methods in domestic environments for smart product development processes. The aim of the study is to create a method for supporting data collection studies in user research of smart products at domestic environments. The study examines the utilization of information and communication technologies in ethnographic data collection methods at domestic environments with a qualitative approach. Two case studies are conducted to understand and analyze the effects of custom designed data collection tools in user research studies conducted at domestic environments. The results of the study revealed that utilization of data collection equipment and methods that are customized to the characteristics of aims and objectives of user research studies, product characteristic and study participants' own environment might lead to the possibility to increase number of study participants and decrease researchers' presence in domestic environments. Additionally, it was found that, sensor kits and internal device logs are capable of supporting user research studies for the evaluation of products, however due to technical complexity and unpredictable contextual factors, triangulation of data collection methods and redundancy of data collection equipment are necessary.

Keywords: Smart products, Ethnography, User Research, Domestic Environments, Data Collection

ÖZ

EV ORTAMLARINDA KULLANICI ARAŞTIRMALARI VERİ TOPLAMA ÇALIŞMALARINI DESTEKLEMEK İÇİN BİR YÖNTEM

Öztoprak, Aydın

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Bu tez, akıllı ürün geliştirme süreçleri için ev ortamlarından veri toplama araç ve yöntemlerini analiz etmektedir. Bu çalışmanın amacı ev ortamlarında yürütülen kullanıcı araştırmalarında veri toplama çalışmalarını desteklemek için bir yöntem yaratmaktır. Çalışma, bilgi ve iletişim teknolojilerinin ev ortamında yürütülen etnografik veri toplama yöntemlerinde uygulamalarını nitel bir perspektifle analiz etmektedir. Özel olarak tasarlanmış veri toplama araçlarının ev ortamlarında gerçekleştirilen kullanıcı araştırmalarına etkilerini anlamak ve analiz etmek amacıyla iki vaka çalışması yürütülmüştür. Çalışmanın sonuçları kullanıcı araştırmalarının amaç ve hedeflerine, ürün özelliklerine ve çalışma katılımcılarının kendi ev ortamlarına göre özelleşmiş veri toplama araç ve yöntemlerinin katılımcı sayılarını arttırabileceğini ve araştırmacıların araştırma ortamında bulunma sürelerini azaltabileceğini göstermiştir. Bunlara ek olarak, duyarga kitlerinin ve cihaz içi günlüklerin ürün değerlendirmesi süreçlerinde kullanıcı araştırmalarını destekleyebileceği görülmüştür, ancak teknik karmaşıklık ve öngörülemeyen bağlamsal etkiler sebebiyle veri toplama yöntem ve araçlarının sağlamasının yapılmasının ve yedeklenmesinin gerekli olduğu anlaşılmıştır.

Anahtar Kelimeler: Akıllı Ürünler, Etnografi, Kullanıcı Araştırmaları, Ev ortamı, Veri toplama

To My Parents

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CHAPTER 1

INTRODUCTION

Started with Mark Weiser's vision (Weiser, 1991) of the computer for 21st century, information and communication technologies have been proliferated into the everyday life in an accelerating rate. Following Moore's Law (Moore, 1965), that processing power of microchips doubles every 18 months, computers are now small, affordable and powerful enough to fit into objects of everyday life to provide extended functionalities and richer experiences to their users.

Desktop personal computers (PCs) which are designed primarily for workplace use have been flourished into domestic environments for communication, entertainment, work and learning activities (Streitz, Kameas, & Mavrommati, 2007). Utilization of desktop PCs, which are the center of computation at home are followed by devices with multiple functions and computational capabilities. These devices are constantly providing information and requesting attention from home residents. Almost all of these devices utilize information and communication technologies such as sensors, processors, actuators and displays to conduct their functionalities.

Miniaturization and affordability of these technologies made them ubiquitous in home environment and started to change the user interaction both with computing and consumer products (Venkatesh, Stolzoff, Shih, & Mazumdar, 2001). Lack of single user single machine type of human computer interactions at home lead to continuous research and development efforts on various interaction styles and products for home environment (Hindus, 1999).

Computers became distributed and specialized for particular activities and physical products got smarter with computational capabilities. They aim to provide complex functionalities and emotionally pleasant user experiences, whereas earlier products and applications were intended for performance and productivity gains. It is now widely accepted in the literature that user needs, expectations and preferences besides contextual factors have significant influence on user experience (Greenberg, 2001; Schifferstein & Hekkert, 2008). Understanding and evaluating these subjective and contextual factors and blending them in new product development process are necessary for products' market success (P. J. Brown, Bovey, & Chen, 1997; Jokela, 2004; Schifferstein & Zwartkruis-Pelgrim, 2008).

Evaluating the usability of products and applications according to performance and productivity metrics in controlled environments has well established tools and methods (Rubin, Chisnell, & Spool, 2008). However, observing users and evaluating products in context present new challenges for user research studies in the human computer interaction field. These challenges might be listed under three major titles such as;

- The requirements of smart product development processes,
- The requirements of user research studies,
- The effects of contextual factors on data collection.

Challenges covered in each title can be listed as follows. Firstly, smart products have significant differences from conventional physical products. They blend computational capabilities of desktop personal computing applications and the physical form of everyday objects. Hence, smart product development process requires a complete understanding of contextual environment and anticipation of user needs and expectations.

Secondly, compared to traditional performance oriented studies in workplace environments, user needs and expectations and degree of satisfaction are highly subjective in domestic environments. Observing activities, anticipating needs and evaluating resulting experiences are necessary for interpreting user interaction with smart products. Consequently, observing activities and evaluating experiences require a thorough observation of user's everyday life. Hence, collecting user specific data from users' own environment without invading users' everyday life is another major challenge for user studies.

Thirdly, the effects of context; the social and physical factors of use environments have effects on both the user and the product. The quality of user experience with the product is dependent on user's and product's interpretation of contextual factors. Therefore, collecting data to predict possible use environments and testing the products against anticipated contextual factors and usage before commercialization is a valuable input for new product development process. However; data collection from real use environments has major technical challenges in terms of equipment design and customization for study participants' houses.

Developing smart products not only requires evaluation of prototypes and concepts, but also requires observation of activities of everyday life. Thus, observation and evaluation of everyday life necessitate alterations in user centered design processes, especially in terms of data collection methodologies. Observing daily routines of social groups have deep roots in social sciences. Ethnography has been proven to be an effective method for collecting data on human social behavior. Hence, ethnographic methods provide opportunities for observing everyday activities for product development processes.

In traditional applications of ethnography in anthropology, ethnographers immerse themselves into the daily routine of target social groups to observe their daily practices. However, immersion of an ethnographer in domestic environments for longer periods of time is not practical. Therefore, utilization of traditional ethnography is not suitable for product development processes. Ethnography has to be adapted for the needs of fast paced product development cycles and short *time-to-market* durations (Masten & Plowman, 2003). Hence, applications and adaptations of ethnographic methods in user studies is widely discussed in the literature (Nardi, 1995; Rose, Shneiderman, & Plaisant, 1995; Siegel & Dray, 2005; Simonsen & Kensing, 1997). The need to adapt ethnography to new product development process and user studies forced scholars and practitioners to refine ethnographic methods for understanding human computer interactions in domestic environments.

As every home is private, presence of human observers for extended periods of time for data collection is not preferable and practical for domestic environments. Therefore, data collection methods of ethnography such as direct observation, shadowing and participation are not suitable for domestic environments.

There are constant efforts to observe domestic environments for user research studies without invading everyday life of house residents. Simulating part of a residential environment in the laboratory (Aarts & Eggen, 2002), instrumenting a residential environment to create live-in laboratories (Stephen S Intille et al., 2006) or installing portable data collection kits (Tapia, Intille, Lopez, & Larson, 2006) in participants' own houses are among the prominent approaches for unobtrusive data collection in domestic environments. These approaches aim to shorten the presence of human observers in the environment and support ubiquitous data collection for longer durations with the participation of increased number of real representative users. Although they provide different scales of data, utilization of technological tools is common for all the approaches.

Utilization of technological tools to observe and understand people's everyday life is named as *Digital Ethnography (Masten & Plowman, 2003).* Digital ethnography aims to collect data from natural environments without disturbing daily routines of residents by eliminating the presence of human observers with the utilization of technological instruments.

In order to extend classical ethnographic methods, data on the everyday routine of house residents have been collected with the help of live-in laboratories (Stephen S Intille, et al., 2006; Kidd et al., 1999), portable sensor kits (Tapia, et al., 2006), probes (Blythe, Park, & Monk, 2004; Gaver, Dunne, & Pacenti, 1999; Hulkko, Mattelmäki, Virtanen, & Keinonen, 2004) and digital device logs (Hilbert & Redmiles, 2000; Kort & Poot, 2005; Morris, Lundell, Dishman, & Needham, 2003). New technological tools such as smart phones, personal mobile computers, various sensor kits, broadband internet connection, social networks etc. are efficient ways to collect user data.

Besides custom designed instruments; internal device logs, technological infrastructures such as global positioning systems, broadband mobile internet connection (3G, 4G), broadband internet connection and standardized communications platforms such as Digital Living Network Alliance (DLNA) provide novel opportunities for data collection. These built-in infrastructures aid researchers by providing the necessary channels for communication and collaboration.

Utilization of technological instruments and infrastructures for data collection provide opportunities for the adaptation of ethnographic methods in new product development processes. Decreasing the study duration, increasing the sample size and removing most of the study burden from participants, and minimizing privacy concerns are some of the major opportunities presented by digital ethnography. Besides these, shorter periods of direct observations, decreased analysis times, reduced travel costs and being able to synchronously observe and record a number of participants are the driving forces behind the adaptation of digital ethnography in new product development processes.

On the other hand, application of digital ethnography raises a number of issues. The major one, as in many of the contextual studies is privacy. Ubiquitous capture and effortless sharing of digital information presents extra responsibilities for researchers in collecting sensitive private data. Issues related to the collection and handling of private data have been repeatedly addressed in the literature (Greenberg, 2001; J. Grudin, 2001; Masten & Plowman, 2003; Soppera & Burbridge, 2004). According to these; control, possession and sharing of data during and after the study are the key components of privacy handling. Once the context, interaction and user experience are represented digitally it can be shared with anyone easily (Soppera & Burbridge, 2004). At this point, technological tools such as audio/video recording, sensors, automatic annotation, high speed wireless networks and data warehouses that streamline data collection procedure; create privacy flaws, therefore special care must be taken while handling the data generated during the study.

Another tradeoff between the fidelity of data and privacy is the degree of representation of context with digital tools. Some scholars agree that the utilization of technological tools causes information loss by the partial digital representation of context in use (J. Grudin, 2001). Grudin (2001) argues that when the context is represented digitally, only a part of it can be captured, which can change the impression it makes or even gives wrong impression. In order to overcome this, more contextual information can be captured but this will, again, result in increased privacy concerns and complexity of data collection process. On the other hand, in near future it is expected that the built environment will be crowded with pervasive computational devices which can collect, annotate and present complete life of ordinary people (Soppera & Burbridge, 2004). Although, highly detailed continuous capture of users' everyday life provides an account of everyday life, this can create huge amounts of data and handling and utilizing it for new product development processes are another challenge for product development community.

1.1. Problem Statement

The characteristics of smart products, the contextual factors in domestic environments and the utilization of ethnography in new product development processes require novel instruments and methodologies that require effective data collection methodologies from domestic environments.

Designer and developer teams need information on actual users' needs, expectations and preferences as well as an account of contextual factors for designing successful smart products. Designers with the lack of this information might have misconceptions of the users and the context. It is commonly argued that user evaluations of smart products and concepts should be conducted in real environments with real users. However, data collection from real environments has major problems regarding the researchers, study participants and the designers.

Formulating a data collection strategy based on user study requirements, product characteristics and contextual factors is a major tradeoff for researchers. Researchers need to balance data requirements against privacy concerns and costs. Low resolution of data might fail to represent usage, product performance and contextual factors whereas a high resolution data might increase privacy concerns of participants, workload of researchers and costs associated with data collection procedure.

1.2. Aim of the Study

Regarding the complexity of everyday actions and routines, there is no single one size that fits all methodology for data collection in domestic environments. However, as suggested by Kuutti (1995), it is possible to isolate activities as basic unit of analysis and target data collection resources and efforts for specific actions, activities and their interaction with the user and the environment. Additionally, smart products are replacing the objects of everyday life and changing our interaction with the environment. Within this context the scope of this study is to devise a method for data collection to support user research studies of smart products in domestic environments. There are 3 components that constitute the structure of the method, which are *product/activity characteristics*, *contextual factors* and *adaptation of ethnographic methods* in new product development processes.

Product/Activity Characteristics: Since smart products are becoming ubiquitous in the environment, observing interactions with them involves observing the activities of users during interaction. Furthermore, observing and analyzing activities of daily life leads to new product ideas and concepts.

Technological capabilities of smart products enable them to collect internal and external data from the environment process it locally to create information and act on this information. Therefore interaction with smart products develops and evolves with time as the product and the user accumulate information about each other. Evaluating the usage for smart products require longitudinal observation of interaction with the product.

Although observation of usage for extended durations of time is not practical for domestic environments, it can be achieved to a particular degree with the utilization of data collection capabilities of smart products. Collecting and analyzing device logs as well as local sensor data collected by the product under study might provide partial digital representation of interaction with the product. Even though, smart product capabilities provide opportunities for observing usage, observing activities to provide information for the design and development of smart product set new challenges for data collection.

Activity theory suggests that specific patterns of operations lead to actions and these actions define activities (Petersen, Madsen, & Kjaer, 2002). Therefore, observing and giving meaning to activities requires different data collection approaches for different layers of activities. For example cutting and chopping food are the operations carried for the action of cooking a meal. Cooking different meals, preparing the table, inviting friends, serving the dinner and cleaning after the dinner are the actions that are carried out for accomplishing the activity of throwing a dinner party.

Moreover, the actions, operations and activities are associated to and activated by the physical and social characteristics of the context (Nardi, 1995). As illustrated in dinner party example; repetitive *operations* constitute lower levels, *actions* constitute mid levels and *activities* constitute higher levels of everyday lives of users. Therefore, these levels pose different requirements for data collection methods. Although, data collection requirements for various levels of activities are different, they also share similar means of data collection. For example in any case of data collection, data must be synchronized among different data sources for reliable analysis.

Contextual Factors: It is widely accepted that user experience is context dependent (Law, Roto, Hassenzahl, Vermeeren, & Kort, 2009). Detaching the contextual factors from user experience observation might lead to erroneous representations. The physical and social contextual factors should be taken into account during the data collection planning and implementation. Physical factors of context pose requirements on data collection instruments whereas social factors of context pose requirements on data collection strategy. For example the temperature, illumination levels, noise and vibration characteristics define which tools to utilize during data collection, whereas the number of people in the environment, their interactions among each other, presence of visitors and communications among them define the strategy and focus of data collection activities.

Handling the data is also context dependent since home is an extremely private environment and provides comfort and safety to its residents. Any intervention during data collection must make sure that residents' privacy, comfort and safety are not distressed. Taking privacy, comfort and safety into account defines the requirements for data collection methodology from participant point of view.

Another set of requirements comes from research design point of view as data collection tools must be physically and mentally invisible to house residents to make sure that data is not affected by the presence of tools itself. Therefore, the design requirements and implementation guidelines of data collection tools in the home environment is a major component of data collection strategy.

Adaptation of Ethnographic Methods: Extending the application areas of traditional data collection methods by utilizing technological tools is an ongoing challenge in the field. Given the sensitivity of domestic environments minimizing the presence of researchers and field visits is a primary goal for scholars. The proposed method aims to support data collection and increase affordability of in context user research by utilizing digital tools such as sensors and data loggers customized for a given research study.

Another aim associated with the adaptation of ethnographic methods is increasing the number of participants in a research study. Ethnographic methods require thorough data collection on low number of participants. Therefore, greatly decreases sample size and increases study durations. The proposed method covers the planning and logistics of conducting data collection at multiple sites synchronously.

Within this context;

"Aim of the study is to create a method for supporting data collection in user research studies of smart products in domestic environments.

1.3. Research Questions

What are the components of data collection in domestic environments for the design and evaluation of smart products?

- Which characteristics of domestic environments have effects on data collection?
- Which characteristics of smart products have effects on data collection?
- What are the determinants of data collection in design and evaluation of smart products?

What is the role of technological instruments for supporting ethnography in product development processes?

- What are the challenges related to data collection instruments for the realization of user research study requirements?
- What is the added value of utilizing technological tools for domestic data collection?
- What are the design requirements of data collection instruments for domestic environments?

1.4. Methodology

In response to research questions a combination of qualitative and quantitative methods are utilized to observe and evaluate the utilization of technological data collection tools in user research studies conducted in domestic environments.

Literature reviews on ubiquitous computing, smart products and user research studies revealed that design and evaluation of smart products require user research studies to be conducted in natural use environments. Based on the literature, the structure of the method for data collection in domestic environments is formulated to facilitate integration of ethnographic methods with technological data collection tools. Subsequently, two consecutive case studies are conducted to provide empirical support for the proposed method.

Finally, the results of the case studies are evaluated with respect to the strengths and weaknesses of the proposed method and the findings of the case studies are compared against the proposed method. As a result of this comparison and evaluation the proposed method is revised.

1.5. *Structure of Thesis*

This thesis is organized in three major parts (Figure 1). The first three chapters constitute the exploratory stage, the fourth chapter presents the proposed method and the latter three chapters constitute the confirmatory stage. Chapter two presents characteristics and capabilities of smart products. Chapter three lists the fundamental challenges and problems of data collection from domestic environments and the opportunities presented with the utilization of technological instruments for the adaptation of ethnographic methods. In chapter 4, the structure of the method for data collection studies is proposed and the methodology and procedure of the research is presented. In chapter 5 case studies are presented and the results of the case studies are discussed. And finally in chapter 6, the thesis concludes with suggestions for future research.

Exploratory Stage	Background Of the Problem Ubiquitous Computing Smart Products Data Collection in Domestic Environments	Chapter 1 Chapter 2 Chapter 3
Proposed System Model	Domestic Data Collection Method	Chapter 4
Confirmatory Stage	Case Study 1 Standalone Sensor Kit Case Study 2 Simple Sensor + Data Logger Couple Findings Findings of Case Study 1 Findings of Case Study 2 Analysis of Instrumented Data Collection Method Discussion Conclusion	Chapter 5 Chapter 6

Figure 1 Structure of the thesis

CHAPTER 2

UBIQUITOUS COMPUTING AND SMART PRODUCTS

In a routine day users explicitly and implicitly interact with dozens of digital devices and exchange information with them. Interactions with most of these devices are routine and their physical forms are invisible to the users. This has been anticipated by Mark Weiser with the introduction of ubiquitous computing (Weiser, 1991). Since then, a number of technology trends have emerged; calm technology (Weiser & Brown, 1996), pervasive technologies (Howard, Kjeldskov, & Skov, 2007), ambient intelligence (Aarts & Eggen, 2002) and affective computing (Picard, 1999) are among the most influential ones with their own conferences and publications.

2.1. Ubiquitous Computing

Started with Weiser's seminal article (Weiser, 1991) and foundational work done at Xerox PARC (Weiser, Gold, & Brown, 1999) the role of computer in users' lives and human-computer interaction undergone a constant evolution. After two decades of work Weiser's vision of invisible computer which "*takes into account the human world and allows the computers themselves to vanish into the background*" is now closer to become a reality. Early examples of ubiquitous computing (Ubicomp) applications only capture location information and provide custom services to the user. Since then, an impressive amount of work on UbiComp has been published and a large number of applications, devices and environments have been developed.

Weiser's vision of many computers for a single user, ubiquitously instrumented environments, networked smart devices, context awareness of digital products and natural interaction styles (Weiser, 1993) have been almost achieved. Today computers in the form factors of tabs, pads, and boards are commercially available for affordable prices. They contain computational capabilities, sensors and actuators for interaction. And they support interaction in a natural style with visual, tactile and voice modalities. Ubicomp systems are context aware and they are able to respond environmental changes and user needs automatically (Abowd & Mynatt, 2000; Posland, 2009).

Conventional desktop computer systems utilize keyboard and mouse interaction for input, whereas ubiquitous systems provide natural ways of interaction. The ultimate goal of ubicomp systems is to use computation as an invisible extension of human body so that users can focus on the task rather than the tool (Weiser, 1991). Making the computation invisible to its user and providing information when needed differentiates ubicomp systems from conventional computer systems. Although the interaction with ubicomp systems is in an anywhere-anytime fashion, it is less obtrusive compared to conventional desktop PC applications. Ubicomp applications stay calm, wait for interaction and provide information when needed. In order to provide these context or user dependent interactions ubicomp systems need to collect data on the characteristics of physical environment. They can sense the properties of the environment, process the data and control the environment if requested or needed. Therefore, the basic characteristics of ubicomp systems can be listed as follows (Posland, 2009):

- Devices with computational components have to share and create information in cooperation.
- Ubicomp devices need to be a part of the physical environment and they should provide natural ways of interaction when needed.
- Ubicomp applications need to be context aware and should provide context dependent information.
- Ubicomp applications can function autonomously to some degree and be sensitive to the balance between human intervention and self governance.
- Ubicomp applications should be intelligent enough to adapt changing social and physical contextual environments.

2.2. Smart Products

The basic characteristics of ubicomp applications, creating and sharing information, natural ways of interaction, context awareness, self-governance, and responsiveness (Posland, 2009) are reflected on physical products and environments. These characteristics serve as design guidelines and provide the technological playground for products and environments that are responsive to user needs. Products and environments that are designed in line with ubiquitous computing trend have been commonly named as smart products or environments. Similarly, products with processors, memory, sensors, actuators, and networking capabilities have commonly been named as smart products (Aitenbichler, Lyardet, Austaller, Kangasharju, & Muhlhauser, 2007; Dhebar, 1996) or intelligent (Rijsdijk, Hultink, & Diamantopoulos, 2007) products[1].

Smartness is now embedded into many devices and environments with sensing, processing and acting capabilities. With these capabilities smart products quickly proliferated into various contexts of use and became a part of leisure, entertainment, healthcare, work and learning activities. Although they have a wide range of application areas, smart products have three major common characteristics (Table 1):

- Data Collection: They collect data about themselves, their users and the context they operate in
- Information Processing: They are able to process information locally or collaboratively with remote devices.
- Acting on Information: They implicitly or explicitly act on information and modify the context accordingly.

Table 1 Characteristics of Smart Products

Smart Products		
Data Collection	**Information Processing**	**Acting on Information**
Self Awareness	Local Processing	Implicit Interaction
Context Awareness	Remote Processing	Explicit Interaction
User Awareness		

In the following sections, the characteristics of smart products will be presented in detail and implications of these characteristics on user research studies conducted for product development and evaluation processes will be discussed.

[1] In this manuscript the term “smart product” will be used to define products with computational capabilities.

2.2.1. Data Collection

Smart products need to collect data about themselves, the characteristics of physical environment and needs, expectations and preferences of their users for performing their "smart" functions. In other terms they need to be aware of themselves (self awareness), the context they operate in (context awareness) and their users (user awareness). Smart products need to utilize sensors, to be aware of their surroundings.

Sensors are micro electro-mechanical systems (MEMS), which are information and communication devices that range from nanometers to millimeters in size. Although they are part of smart products they are also named as *smart dust* because of their form factor and data collection capabilities (Posland, 2009). Smart dust devices are generally used for data collection and they can be embedded into physical products, environments and even into humans. The most common MEMS devices are accelerometers that are embedded in almost all of the smart phones today. Accelerometers can sense the movement of the device and provide information on the orientation, acceleration and speed of device in real world. One of the many uses of accelerometers is fall protection. For example if a device with a built-in hard drive senses that it's falling, it automatically shuts down itself to minimize data loss and damage to the disks.

2.2.1.1. Self Awareness

Self awareness is achieved by collecting information about the state of the product for functional purposes to make sure that a certain level of quality of service is achieved. Internal sensors and device reports are utilized for this type of data collection. Devices need to know what their statuses are, what functions are available and what functions can be performed. Moreover, functionality and performance of a self aware device changes based on the data collected on the current state of the device.

Self aware systems implicitly monitor themselves to provide better services and user experiences for their users. They take autonomous decisions to increase their performance; however, developing smart products with these functionalities requires thorough user research studies to ensure the smooth user interaction with the product (Rijsdijk, et al., 2007). Evaluating smart products based on predefined tasks in a controlled environment might provide data on the performance of the products, nevertheless understanding user and device responses and interaction in real time scenarios require evaluation in context with real users and activities.

2.2.1.2. Context Awareness

The goal of smart products is to provide services whenever and wherever needed without giving burden to its user. In order to achieve this goal, smart products need to understand the social and physical context to customize their actions. Any given smart product might need different degrees of contextual information. For example some products might only need temperature of the environment to operate whereas some others might need, geographical location, physical orientation, identification of other devices, presence of users, time of the day, date etc.. Hence, defining context is essential for developing and evaluating context aware smart products.

Definition of Context

There is constant effort in HCI community to define the environment in which the information systems operate and the user-system interaction takes place. In 1994, when the term context-aware first coined by Schilit and Theimer (1994), context was outlined as location, identities of nearby people and objects and changes to those objects. In similar definitions, physical factors and time are added and context is defined as location, identities of people around the user, the time of the day, season, temperature and so forth(P. J. Brown, et al., 1997; Ryan, Pascoe, & Morse, 1997).

These early definitions were computer and application oriented and did not pay enough attention to the users. Dey (1998) is the first author to add users' emotional state and focus of attention to the definition and identified context as the users' emotional state, focus of attention, location, orientation, date, time, and objects and people in the user environment. Although Dey's definition was much more user oriented, still users' preferences interests and the social world in which the interaction takes place was not covered by the definition. Dey, Abowd and Salber (2001) reviewed this definition from a user centered design perspective to provide a user centered understanding for context aware systems, applications and products. Dey, Abowd and Salber's (2001) definition of context is;

> *"Context; any information that can be used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity, and state of people, groups, and computational and physical objects."(Dey, et al., 2001, p. 106)*

This definition points out characteristics of context and identifies elements (identities, locations, status and time) for categorizing context. Classifying contexts according to these elements and acting correspondingly might be useful in designing and evaluating context dependent objects. Instead of giving a complete definition of context Abowd, Mynatt (2000) proposes answering “five W’s” (Who, What, Where, When and Why) for assisting context aware applications. Among these five W’s “Why?” is the most difficult piece of context to understand, as everybody has some unique reasoning. The unique reasoning and irregular activities of users might be because of their “*intentions, emotions, likes, dislikes, phobias, perceptions, interpretations (misinterpretations), and many other motivators*.”(Bellotti & Edwards, 2001). Although capturing these motivators with various sensors might be a good starting point for understanding why users did something, there are privacy issues limiting the capture of this data.

Based on the definition of context from the design and evaluation of smart products perspective, the characteristics of contextual environments can be divided into three main titles according to the physical, social and technological features of context (Posland, 2009).

Physical Context

The physical context stands for the physical features of the environment, such as; location, temperature, humidity, vibration, weather conditions and so on. Smart products collect data on these features of the natural and built environment, process it and convert them into context specific information and actions. Based on the local physical factors smart products differentiate functionalities, and customize interactions. For example the brightness of a digital screen can be adjusted according to the light intensity of the environment. Another example is the smart thermostatic controls of air conditioning systems, which adjust indoor air temperatures according to the outdoor temperatures to save energy and provide comfort to their users.

In some cases smart products utilize networking and remote data sources to infer local contextual features. For example inferring the location of a device requires communication with global positioning system (GPS) satellites or cellular network towers or both, if the device is indoors. With accurate realization of location information smart devices can pull location specific data from remote servers. For example ambient umbrella

("Ambient Umbrella," 2008) monitors local weather conditions via a web server and reminds user for an approaching rain.

Designers and developers of smart devices need to anticipate the effects of physical conditions on the interaction with the product. For the design and development of conventional products designers' mere concern is the user, however with smart products they also need to anticipate the behavior of the product in real physical conditions. Moreover, these physical conditions might change in the orders of milliseconds to months, hence the product should be aware of these changes and should provide interactions accordingly.

Anticipation of smart products' behavior under the effects of physical contextual factors requires testing and evaluation in actual context during product development process. With the information collected in development phase, products can be designed to cover a range of physical conditions and their variations in order to provide their smart functionalities flawlessly.

Social Context

Another characteristic of use context is the human presence at the environment. Data about the presence of the user(s), other parties, detection of public or private environment etc. need to be collected for privacy management (Soppera & Burbridge, 2004) and interruptability (Kern, Schiele, & Schmidt, 2007). As smart products heavily rely on data about users' personal information, handling this information raises privacy issues. In addition to this, smart products need to infer when to attract and release users' attention based on the importance of the message and the social context. A smart product or application should not interfere a conversation and ask for private preferences in a public context. For example, a smart application might infer that the user is performing a presentation, and might postpone messages that need user attention.

Inferring social context has many ubiquitous applications that might be useful for their users. Devices can detect the number of users in the environment, who they are, and what they are doing and eventually what they need. Inferring such information requires a group of smart devices to work in cooperation and communicate with each other. In an early application of ubiquitous environments, Classroom 2000 (Abowd, 1999); the instrumented environment captures a conventional lecture, takes class notes and e-mails the notes to the participating students. In this experimental setting more than 60 courses have been conducted and it was found that conducting user studies in actual environments is crucial for ubiquitous environments and smart products.

Social characteristics of contextual environments are almost impossible to simulate in controlled environments as they are by definition controlled. The reactions of the user, friends and family or even complete strangers might have effects on the user experience with a smart product and environment (Battarbee, Koskinen, Hendrik, & Paul, 2008). Hence, it is a necessity to observe and evaluate products in real everyday use environments.

Technological Context

Smart products need a number of internal and external services and infrastructures to function effectively. Presence and quality of these services and infrastructures heavily influence their operation. Hence, they need to collect data on the presence and quality of technological infrastructure. Being aware of peer devices, their capabilities and possible collaborations among these devices might increase the quality of service and user experiences. Opening a simpler version of a webpage in a slow network environment and the full version in faster network environment is a good example of adaptability to technological context.

Smart products heavily depend on the network infrastructure to retrieve and send data, which is invisible to the user. Being not aware of the network quality, users might get frustrated because of a non functioning device. For example GPS works best in clear sunny days and fails in cloudy days. If the user is not aware of the effects of GPS infrastructure he/she will be frustrated by the wrong location approximations.

Data collection on the state of technological infrastructures is an important component of smart products. More importantly, the representation of this information is also crucial for users to understand both device state and infrastructure status. Testing and evaluation of smart products for technological context is usually done in controlled testing environments. Although infrastructure status might be perfect at testing facilities, it might be faulty at different geographical locations, use environments or specific user interactions. For example Apple™'s well known IPhone4™ suffered attenuated signal reception because of certain holding style with left hand (Silverman, 2010). Although IPhone4™ has been rigorously tested before market release; this antenna issue has been overlooked. When it was used by real people in real technological environments users immediately figured out low signal reception and experienced dropped calls.

Conducting user observation and evaluation studies with various technological contexts might help designing functions and scaling capabilities of smart products with regard to the characteristics of technological context. For example, mobile network communications rely on various communication standards such as 2G, 3G, 3.5G and 4G etc. that define network bandwidth. Mobile devices automatically detect the network standard and adjust the quality of their services based on the available bandwidth for providing best user experiences. Consequently, observing the adaptation of devices to the technological context and the resulting user experiences require an always on data collection strategy that needs to monitor devices, technological context and user interaction as a whole.

2.2.1.3. User Awareness

In line with ubiquitous computing goals, smart products aim to meet user expectations by supporting user activities in a natural way. Hence, they need to collect data on the presence of users, their intentions, needs, expectations, emotional moods, aims, goals and preferences. This user dependent information can be manually entered or automatically inferred from analysis of contextual factors or user activities by smart devices. For example a camera that is able to detect faces and face mimics can guide its user for best shot that captures smiling faces.

Smart devices and environments can be programmed to act according to the identification of certain individuals, specific groups of people or large crowds for private or public use situations. For public use environments smart products work with aggregated user information to provide best possible user experience without invading individual’s privacy. Being aware of the user identity, collecting user specific information and sharing it with networked devices provide user experiences in the expense of user’s privacy.

User awareness of smart products can be handled in various levels for ubiquitous computing applications. For example tracking the location of a specific individual’s mobile phone might be a severe violation of privacy but tracking the location of all the mobile phones in a city in an aggregated way for a smarter scheduling and route planning of public transportation system is not a violation at all. Today, people share their private information regarding to their identity, location, family links, relationships, friend circles and events that they are organizing or attending in virtual social networks with hundreds of million members. There is constant effort to help users in managing their privacy settings (Squicciarini, Shehab, & Paci, 2009) with minimum effort to avoid privacy hacks and frauds.

User aware systems store significant amount of information on experiences, expectations and needs of users, they couple this information with other context specific information such as location, weather, noise, presence of other people and technological infrastructure to customize their services. Sharing the amount of private information with smart products is totally subjective to their users. It is a tradeoff for the users whether to benefit customized services or to protect private information. In some cases users might be precautious and prefer not to share private information such as while they are working on public computer terminals or sometimes they feel safer to share information on a secured home or work network. Therefore, understanding these concerns and designing user aware systems requires observing users in real contexts of use.

2.2.2. Information Processing

Ubiquitous computing applications collect data from various sources such as real time sensing tools, user input, stored information and network. They utilize this data to synthesize information for supporting their users. Data processing capabilities differentiate smart products from conventional physical products. With current trend in processing power capacities, smart products will be able to make autonomous decisions more frequently in near future. Although processing power per centimeter square of a microchip has increased significantly, demanding applications still require power and high performance computers. Therefore information processing capabilities need to be scaled and distributed among devices (Cook & Das, 2004). Information processing might be handled locally or remotely based on the computation tasks at hand.

Local information processing utilizes computational capabilities built in the product. Generally, built-in computational capabilities are limited with the power requirements of the device as computation requires continues supply of energy. Hence, smart products with local processing capabilities provide limited user experiences compared to smart products that utilize remote information processing.

In the last decade the increased usage of large computation warehouses, *the cloud*, lead the way to affordable supercomputing (Hayes, 2008). Cloud computing or on-demand computing works on the notion of time sharing which was the very first method of utilizing computers almost 60 years ago. Today, even the tiniest device with a network connection can benefit incredibly complex computational capabilities with the help of cloud systems. Networking and remote processing capabilities enable smart devices to act as supercomputers and opened a new era for human computer interaction.

With remote information processing even the smallest mobile device has the ability to utilize artificial intelligence algorithms to act autonomously. Smart products that have autonomous decision making capabilities are in charge of their own actions to some degree. They minimize user interaction by receiving higher goals and policies from the user and they plan their actions to achieve those user defined goals in line with predefined policies (Posland, 2009).

Remote processing smart products are more "intelligent" than local processing products; however they need network connectivity which might not be available depending on the technological contextual factors. Both local and remote information processing smart products are highly dependent on contextual factors, such as user preferences and goals, physical contextual factors and technological contextual factors. Hence, design and evaluation of smart products require a thorough understanding of contextual factors to scale their computational and networking capabilities for providing better interactions.

2.2.3. Acting on Information

Smart products collect and process data to act on the resulting information for providing user centered services. As a policy of ubiquitous computing, these services might not be visible to their users. For example walking into a room can be enough for a smart system to infer user's presence and direct phone calls to that room. Even if a phone call is not received and the user is not aware of the interaction, the system provides services for its user. Although the aim is to interact with technology in a natural way, interaction is not fully concealed with smart systems. Users need to interact with smart products explicitly at least for initial setup and customization of the products according to their preferences. Even though smart products' interactions with users show extensive diversity, they can be categorized in two major groups such as; implicit and explicit interactions (Cook & Das, 2004; Posland, 2009; Streitz, et al., 2007).

2.2.3.1. *Implicit Interaction*

Products with implicit interaction are generally ubiquitous in the environment and they infer information autonomously from the contextual environment or from remote sources. Then they present information with ambient interaction modalities that do not need direct attention from the users. They catch and release user attention several times, usually while the user is conducting some other tasks. Smart products with indirect interaction have challenging data collection requirements for user research studies as interaction with them is spontaneous and difficult to track. Although traditional methods of usability evaluation do not cover indirect interaction modalities there are efforts to set up frameworks for user research studies for smart environments (Consolvo, Arnstein, & Franza, 2002) and ambient displays (Mankoff et al., 2003).

Extreme popularity of desktop and mobile personal computers both at domestic and workplace environments have made the *Window Icon Menu Pointer* (WIMP) user interfaces the dominant interaction paradigm for the last two decades and they are still the most popular interaction style (Jacob et al., 2008). However, the diversity of computational artifacts and the diffusion of information and communication technologies into everyday products necessitated natural interaction modalities. Various technologies such as speech, gesture, touch and haptic interfaces support natural interaction with computation.

Point-and-click style of interaction and extensive usability studies on the subject made desktop computing available and easy to learn for millions of people. With the departure of computation from desktop to naturalistic use environments, usability community need to make sure that post-WIMP interfaces fill the gap between digital information and physical objects that have built-in computational capabilities. Van Dam (1997) defined post-WIMP interfaces as an interface which is *"…containing at least one interaction technique not dependent on classical 2D widgets such as menus and icons."* This early and general definition covers ubiquitous (Abowd & Mynatt, 2000), pervasive (Howard, et al., 2007) and affective computing (Picard, 1999), tangible and graspable interaction styles (Ishii, 2008), virtual (Bowman, Gabbard, & Hix, 2002), mixed and augmented reality (Bowers et al., 2007) as well as handheld and mobile devices (Ballard, 2007). Although some of these interaction styles and high level frameworks are considerably different from each other, the diversity of new interaction styles and efforts on developing these technologies indicate the next generation of human computer interaction.

Although post WIMP interfaces provide new modes of interaction the user still interacts with a computer. On the other hand, with tangible interfaces users interact with physical objects. Capturing user interaction with physical objects and utilizing it as an input for computational capabilities of physical objects provides novel opportunities and challenges for data collection for user research studies. Hence; instead of reviewing extensive work in post-wimp interfaces, this study will focus on tangible user interfaces (TUI) (Ishii & Ullmer, 1997) and reality based interactions (Jacob, et al., 2008) that are early and late examples of implicit interactions with computation.

Ishii and Ullmer`s (1997) tangible user interface definition reveals key concepts of post WIMP interfaces. They defined TUI as user interfaces that "*augment the real physical world by coupling digital information to everyday physical objects*.(Ishii & Ullmer, 1997, p. 235)". In parallel to Weiser`s (1991) vision of the invisible computer and natural interaction various prototypes of TUI have been designed and tested in the last decade. For example, UrP (Urban Planning Workbench) (Underkoffler & Ishii, 1999) utilizes 3D frames as scaled architectural building mockups to control and manipulate urban planning simulations projected on physical workbench. Multiple users can manipulate physical objects for manipulating the digital representation of urban environment and they can observe the shadows, reflections and wind flow paths etc. real time on the urban map represented on a physical workbench. Instead of generic input and output devices (keyboard, mouse, computer screen) UrP utilizes scaled mockups and a physical workbench. Moreover the control and the display of the information coincide, which makes the tool (computer) invisible and blended to the environment.

Although it has been almost a decade after Van Dam`s definition of post-WIMP interfaces there is neither settled nor generally agreed definition of post-WIMP interfaces. There is continuous effort (Fishkin, 2004; Hornecker & Buur, 2006; Jacob, et al., 2008) to create a framework for defining, classifying and categorizing new interfaces and interaction styles. However, there is limited work on the user centered evaluations of new interaction styles in real environments (Hornecker, 2011). This might be due to the prototypical nature of new applications; most examples of post-WIMP interfaces are installed in research laboratories and used by researchers themselves. For example; Adaptive Home project was installed and evaluated at Michael Mozer`s own home, he was the designer, user and evaluator of the system(Mozer, 1998).

Jacob, et al., (2008) proposed a framework, *Reality-Based Interaction*, that unites emerging interaction styles. According to Jacob et al. direct manipulation paradigm of graphical user interfaces (GUIs) moved to next level with post-WIMP interfaces, in which the user manipulates the computational objects physically in a natural way instead of using generic input devices for instructing the computer to manipulate digital objects. Besides the software interface, the physical interface has to be designed and evaluated for better usability. With post-WIMP interfaces the physical object is no longer what it looks like, besides its apparent physical function it has to transmit its computational functionalities as well. Louis Sullivan`s famous motto "form follows function" for architectural and industrial design might be applied to the design of smart products that incorporate tangible interfaces in order to communicate the computational capabilities as well as the physical functions of products with their users.

2.2.3.2. Explicit Interaction

Similar to conventional interfaces, smart products with explicit interaction require direct input from users and/or provide output that the user needs to engage and pay attention to conduct tasks. However, explicit interactions with smart products are usually limited to initial setup and customization of products. For example a smart phone, car audio system and even the safety systems of the car can cooperate to provide hands free operation of a telephone via Bluetooth™ connection. When the driver enters the car, smart phone and car audio system handshakes and create a network for supporting driver for receiving and making calls during driving. In addition to these, car safety systems can monitor incoming calls and reject or hold calls based on the presence of driving conditions that require full attention of the driver. Although, these interactions between the car, smart phone and the driver are implicit, the driver needs to set up all these smart systems at the beginning. The phone and the car must be "*introduced"* to each other for future cooperation. This requires explicit input of information both to the car and to the smart phone. Moreover, the driver needs to set preferences whether he/she wants the car to take autonomous decisions to reject or accept calls.

Smart products' capability of logging user events provide opportunities for observing and evaluating explicit interactions with smart products as user interaction with the system can be recorded automatically for further reference. However, cooperation of multiple devices for achieving particular tasks, as in the hands free operation of smart phone, requires observing the complete user environment in terms of infrastructure and other devices.

Smart products generally incorporate both explicit and implicit interactions during actual use; hence, user research studies of smart products must include complementary tools and methods to observe both interaction modalities.

Smart products’ data collection, information processing and acting on information characteristics and resulting user experiences all require user research studies conducted in real contexts of use for smart product design and development processes. Hence, designing user research studies in real contexts of use entails a broad understanding of user experience, data collection tools and methods and contextual factors. In the next chapter a detailed account of data collection in domestic environments with respect to the requirements of user research studies and characteristics of domestic environments will be presented.

CHAPTER 3

DATA COLLECTION FOR USER RESEARCH STUDIES IN DOMESTIC ENVIRONMENTS

Multifunctional, customized and context aware products that require physical, social, hedonic and cognitive aspects of human computer interaction fostered user research studies on users' experiences with technology. In the last decade a significant body of information has been built up and observing, designing and evaluating user experiences has become an independent field of research with its own conferences and journals. As user experience[2] is a wide, multidisciplinary field, it will be discussed in terms of data collection for the design and development of smart products. In order to stay in the aim and scope of this study observing actual interactions with smart products in domestic environments will be discussed in this chapter.

3.1. User Experience

There are multiple definitions of user experience regarding the design and development of smart products. Some of these definitions focus on individual user, some focus on social use and some others focus on the continual nature of experiencing.

In one of these definitions that focus on individual user Alben (1996) define experience as;

> *"…all the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they're using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it." (Alben, 1996, p. 12)*

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[2] Although, user experience (Hassenzahl & Tractinsky, 2006; Tullis & Albert, 2008) or product experience (Alben, 1996; Schifferstein & Hekkert, 2008) are widely accepted terms, user experience will be used throughout this manuscript.

Alben's definition focuses on individual user's physical and cognitive perception of interaction with product and the matching of user's aims and expectations with the qualities of interaction and the context in which the interaction takes place. According to this view observing the interaction, understanding the subjective perception and collecting data on the contextual environment can provide information on the quality of experience.

Battarbee (2003) approaches user experience from social use perspective and states that *"interacting with other people is the basis of making sense of experiences at all."* According to her, product experience should be analyzed in coordination with feelings, actions and emotions in order to capture the aims, effects and the meanings of experiences. Observing them in social interaction will provide the pattern behind evolution of user experiences and might provide information on design and development of smart products.

In a more holistic approach, Forlizzi and Ford (2000) identified three categories of experiencing a product, which are *"experience, an experience and experience as story"* where; e*xperience* is the core element to recognize a passing experience and it only has a reflection on the individual self. *An Experience,* on the other hand, has a reflection on the individual, product and the environment that experience takes place. Finally, communicating *experience as a story* happens when the user has something memorable about an experience and shares them in certain other contexts with various audiences. As Forlizzi and Ford argues that the way we talk about experiences or the way we experience a product changes over time, McCarthy and Wright (2004) states that in order to make sense of an experience, users remember the past, analyze and interpret the moment and anticipate the future. Our earlier experiences and expected future have effects on how we interpret and talk about the experience we have.

Although there are different approaches to the definition of user experience, making sense of interaction with the product and creating an individual representation of this interaction is common in all of them. According to this, users interacting with the same device might have different user experiences due to their background, needs, anticipated future and socio-physical factors in contextual environments. Users' background and anticipated future are subjective and might be collected with self report tools and methods, however, the quality of interaction and the effects of socio-physical factors on interaction in contextual environments require ethnographic observation of product use for user research studies.

Besides observation of use, observation of everyday life is also essential for user research studies as designers are not immersed into real contexts of use. This separation from real users and contexts leads to a technology driven design process instead of user centered design process (Endsley, Bolté, & Jones, 2003), consequently feeding contextual information on real users and activities of everyday life is essential for the design and development of successful smart products. In line with this view Hassenzahl states that;

> *"Designing an experience (and according products) requires a detailed understanding of the people and the context it is designed for. In addition, designers need inspiration. They are able to build ideas from anecdotal observations and loose associations. Certainly, a bottom-up, ethnographic approach and method is able to provide this. It urges us to leave our laboratories or studios, to meddle with real people, in the real world."(Hassenzahl, 2010, p. 74)*

Even though observing everyday life, interactions with smart product and the effect of contextual factors on these interactions in real use environments are essential for smart product development and evaluation studies, utilizing ethnographic methods set challenges for data collection in user research studies. The presence of human observers in users' houses for extended durations of time and frequent house visits are burdensome. Moreover, presence of human observers influence data collection and over reliance on self report tools such as interviews is subject to selective reporting and recall errors (Strauss & Corbin, 1990).

Observing interactions, contextual factors and everyday routine of house residents to inform the design and development of smart products require new data collection strategies, since the tools and methods of traditional task centric user research studies are based on single user single device interactions in predictable environments such as workplaces (Bell, Blythe, Gaver, Sengers, & Wright, 2003). Requirements of user research studies can be listed in the following titles to support the development of smart products.

- Observation of users' everyday life for longer durations.
- Data on mundane repetitive tasks and daily, weekly and seasonal routines.
- Unobtrusive data collection tools for domestic environments.

- Data on interaction with products coupled with contextual factors.

3.2. Implications of in Context User Research Studies on Data Collection

Hassenzahl and Tractinsky (2006) describe the process of experiencing a product in three major stages. According to them, experiencing starts with the perception of the product and continues with the creation of personal representation of product in user's cognition. Finally, as a result of product's cognitive image and use context, users experience the emotional and behavioral outcomes of interaction. This approach conforms to the overall tendency of HCI studies to move from mere problem identification and solving to the proactive approach in which user research studies aim to identify and develop pleasant interactions for users. It is argued that usability ensures an efficient and effective user interaction; however, usability is necessary but not sufficient in achieving interfaces that are highly acceptable and adoptable (Law, Vermeeren, Hassenzahl, & Blythe, 2007).

Conducting user research in real contexts of use is a multidimensional and a complex field of study as products, users and contextual factors are the key variables. Given the complexity of the subject, in context user research study requirements on data collection studies will be discussed with respect to product qualities, social characteristics of use, contextual factors and self representation of users.

3.2.1. Product Characteristics and In-Context User Research

Characteristics of smart products (see Section 2.2) facilitate experiences which are more engaging than interacting with conventional desktop systems. However, designing the user experience of a smart product can be challenging as smart products are always on and constantly require information to carry out their smart functionalities. Moreover, they frequently interrupt users and ask for attention which might be overwhelming or inappropriate based on the contextual environment.

Alben (1996) defined 8 qualities of products that have effects on creating pleasant user experiences with products. These qualities are listed as; *manageable, mutable, aesthetic experience, appropriate, learnable and usable, understanding of users, effective design process,* and *needed*. Five of these qualities, *manageable, mutable, appropriate, learnable and usable* and *needed* are directly related to the data collection studies for designing user experiences. Observing *manageability, mutability, learnability* and *appropriateness of a* *product* require observation of the contextual environment for longer periods of time in real use environments. For example, in an experimental study (S. Intille & Ho, 2005), interruptions from a mobile device is studied by comparing interruptions at random intervals to activity based intervals. The study utilized wireless sensors to infer user activities in context for a complete day to collect data on users' experiences with interruptions from mobile devices.

Similar to this, understanding domestication and adoptability of a product require a combination of qualitative and quantitative data collection methods. Collecting efficiency and effectiveness of conducting particular tasks in different contextual settings and over time can lead to reliable accounts of user experience. For example, in a six week in depth ethnographic study (Karapanos, Zimmerman, Forlizzi, & Martens, 2009), it was observed that initial hedonic qualities of a product have weaker effects on extended use over time.

As experience is something continuous and evolves through product life span (Forlizzi & Ford, 2000), users create a cumulative account of interaction based on the frequency and quality of interaction with a product. Therefore products need to evolve over time to sustain pleasant interactions throughout complete life cycle. Designers need to have an understanding of not only the context and task definitions but also the frequency and duration of certain tasks. For example, user experience of a novel TV set was observed in a six month study (Petersen, et al., 2002), and revealed that users tend to forget interfaces that they don't use frequently and learn them better when they have a motivation to use.

Data collection studies for the design and evaluation of complex and multi-functional products need to;

- Collect data for longer durations of time without invading the user environment.
- Collect data on transformations of user experiences over time,
- Collect data continuously as smart products are always on and ready for interaction
- Provide information on possible use situations in order to immerse designers to the actual use context and familiarize them to the users and the context.

3.2.2. Social Characteristics of Use and Data Collection

Social characteristics of use define the interactions among users, other parties, the product and the environment. Understanding and observing social characteristics of use provides information on users' subjective representations of interactions. How users make sense of the experience and how they communicate these experiences have roles on product attachment and frequency of use (Battarbee, 2003; Forlizzi, 2007).

McCarthy and Wright (2004) argue that experiences are formed in the context of users' background and foreseeable future, they identified four threads of experience; *sensual, emotional, compositional and spatiotemporal threads (McCarthy & Wright, 2004, p. 79)*. Those threads cover how we perceive an interaction with our sensory system, the emotional response based on this sensual perception, perceived beginning and end of experience, the interplay between the parts and the whole of experience, and finally, the space and time component of experience. According to McCarthy and Wright, experience is highly dependent on individual's aims, needs and values, yet they added that experiences enrich by sharing them with others. The stories users create on their experiences with technology and the responses they receive from social interactions enhance the quality of experience.

Battarbee (2003) argued that certain experiences can only make sense when they are raised to social attention. She names social user experience as *Co-experience* and defines as *" …the seamless blend of user experience of products and social interaction" (Battarbee, 2003, p. 109)*. She argues that creative interactions with products, which might not be anticipated by the designers, are most likely to happen during social interactions and these creative interactions lead to better user experiences. In order to achieve more engaging products, these user experiences should be captured and used during interaction design process.

Forlizzi (2007) approaches social product use from a different point of view and discusses the effects of product interaction on groups of people. It is a fact that products evoke different kinds of emotional responses on individual users; however there is limited information on the social, emotional responses of interaction in between groups of people and products. As public use of interactive technologies is increasing and more devices are supporting multiple synchronous interactions of users, new data collection strategies are required to understand these interactions.

Data collection for individual user studies can be conducted by users' consent; however collecting data in a social context limits the control over users in the environment and create privacy issues. One approach to handle privacy is to collect data anonymously right at the beginning of data collection, which is more suitable with data collection with automatic tools such as sensors and device logs. Another approach is to handle privacy before analysis phase by aggregating the data and removing the parts of data that can be used to identify participants. For example, Mackay (1995) proposed a set of preliminary guidelines for the utilization of video recordings for observing human computer interaction studies.

Social characteristics of use suggests that communication and social interaction among users alters how users perceive and make sense of product qualities and functionalities, iteratively, this social image has strong effects on how individual users perceive the product and express themselves based on this shared understanding of product image.

Marketing and product design literatures suggest that individuals express their self (moods, emotions, identity, status, economical power etc.) via physical artifacts and possessions (Hassenzahl, 2004b). Expressing self with the products is a social function for defining one's identity in a social community among relevant others. For example, Greenwald (1988) identified four aspects of self, *the diffuse self, private self, public self* and *collective self* to define subjective product meaning for an individual in order to explain product attachment. According to this model consumers define different self identities to create product representations for *enjoyment, individual autonomy, group affiliation* and *life vision* (Figure 2).

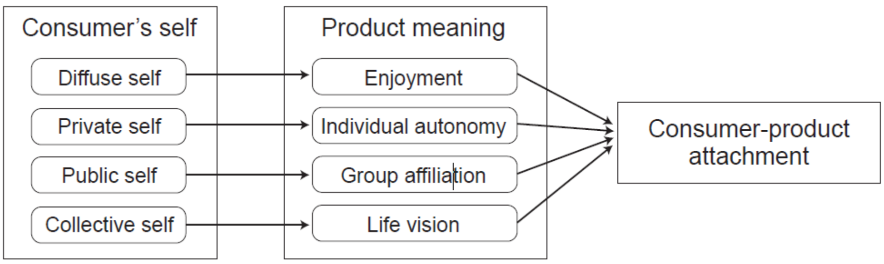


Figure 2 Conceptual model of product attachment (adapted from Schifferstein and Zwartkruis-Pelgrim 2008, p3)

Similarly, Schifferstein and Zwartkruis-Pelgrim (2008) argued that products, to some degree, are extensions from one's self and they both serve to instrumental and emotional needs of users, and this self extension leads to product attachment if both of the needs are satisfied with the product. Schifferstein and Zwartkruis-Pelgrim (2008) utilized Greenwald's (1988) four aspects of self in explaining product attachment. According to them *diffuse self* is responsible for hedonic responses, *private self* relates to individual achievement, improvement and meeting personal goals, *public self* defines individual's image among relevant others and *collective self* looks for being part of a social group or a community.

In an early attempt to identify the relationship between an individual and belongings, Ball and Tasaki (1992) identified 5 stages of attachment based on product life span; *pre-acquisition, early ownership, mature ownership, predisposal and post-disposal*. These stages might work for almost all physical products; however for software products certain phases of these stages should be ignored. Currently millions of developers worldwide develop and sell software for mobile handheld devices. Although these software packages deliver unique experiences, they don't have a physical body and the interaction can only make sense when these experiences are shared.

With the boom of social network platforms on the WWW, millions of people worldwide create and share digital content based on their physical daily experiences and create a personal story and public identity which are nurtured by both the digital and physical experiences (Swallow, Blythe, & Wright, 2005). Hassenzahl (2004b) argues that expressing self to relevant others is a need for individuals as they like to convey better public images of themselves.

Data collection on self expression might be the most challenging part of data collection studies for user research studies as users try to build better social images in user research studies. Figure 2 demonstrates the levels of self representation; according to this model, diffuse, private, public and collective self representations are related to product meaning and leads to the product attachment. With self reporting data collection tools and methods (see section 3.5.3.2) users reveal their public and collective self representations and product meaning. Hence, the diffuse and private self representations of product use are overlooked and users tend to respond with socially acceptable answers to user research inquiries. In order to capture the differences between user reports and actual events user data must be collected with ethnographers or external data collection equipment as well as self reporting tools.

Live-in laboratories (Stephen S Intille et al., 2005; Kidd, et al., 1999; Taylor et al., 2007) are proposed as a solution to this problem and they are among the popular tools to collect data regarding the self representations of users. Live-in laboratories provide non obtrusive natural environments for comparing what users do and what they say they do; however they are expensive to build and maintain, and yet they are still not the real environment of study participants.

Participants move in these laboratories for study durations and expected to continue their normal daily routines during the study. Their activities and communications are captured to infer user experiences generated by certain products. The way they react to and communicate these experiences are all captured for analysis. Although, live-in laboratories seem promising for data collection, number of participants and study durations are critical for these studies, moreover the costs associated with these long term studies are relatively high.

In contrast to live-in laboratories, probes are low cost design oriented data collection tools that are based on self documentation and representation (Mattelmäki, 2005). Although they have a general definition, 5 main characteristics of probes are; their functionality, flexibility, usability, logging capability and their support to design activities.

The aims of the probes, although they are quite flexible, are to watch and record the technology use over time and gather information about the users, to field test the technology, to watch and inspire ideas by provoking the users to reflect on and verbalize their experiences, feelings and attitudes, to visualize their actions and contexts and to inspire designers for the realization of new technologies (Gaver, et al., 1999). Since probes are self documented, users can express themselves with an array of tools such as collages, photographs, video clips or simple text. One or more of these tools can be utilized; however being redundant might be useful to make sure that users share their real experiences.

3.2.3. Contextual Factors in User Research Studies

Sculpting and customizing experiences depending on different use contexts is a major challenge for HCI community. There has been constant effort to understand and observe contextual factors that might feed smart product design and evaluation.

It is well listed in the literature that that contextual factors and information should be taken into account during the design process and context information should be a part of the product. (Forlizzi & Battarbee, 2004; Hassenzahl, 2004b; Keyson, Hendrik, & Paul, 2008; McCarthy & Wright, 2004). Perceiving the context and making sense of it is highly subjective and requires cognitive activities in user's mind and these activities invoke unique physical and emotional responses. Hence, an individual interacting with the same product in different contexts will have different experiences.

Field studies, live-in laboratories, rapid ethnographic methods and probe studies are among the many approaches for collecting data to understand the role of context in user research studies. In addition to these, exploiting the readily available contextual information stored in digital devices provide opportunities for unobtrusive data collection. With increasing number of sensors utilized in each product, it is now possible to infer chunks of use context, especially location and user identity, and deliver unique experiences based on this information.

Contrary to the individuals, smart objects collect quantitative data from the environment and interpret it based on preprogrammed algorithms. Traditional usability practice focuses on observing and eliminating the gap between users' cognitive model of the interface and the actual working of the interface.

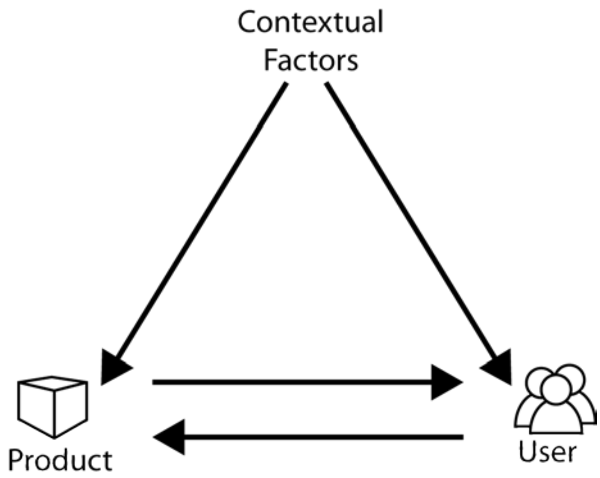


Figure 3 Interaction among user, product and contextual factors

In addition to users' understanding of context, smart products' inference of context also plays an important role for in-context data collection. User research studies have to focus on the interaction between contextual information, how products and users interpret this information and finally how this information alters the interaction between the user and the product (Figure 3).

3.3. Evaluation of Smart Products

As for all the design disciplines, smart product designers and developers need a clear definition of their subject matter; what are the dimensions, components, qualities of product use, what makes some interactions more engaging, more pleasurable or what makes some experiences dissatisfying and burdensome should be identified for product design processes. In response to this problem, utilization of commonly accepted evaluation methods, metrics, measures and guidelines for the design and evaluation of smart products is proposed (Scholtz & Consolvo, 2004). Consequently, data collection requirements of user research studies are identified by metrics, measures and guidelines of commonly available user evaluation studies.

Users' background, interaction with products and reflections of this interaction on anticipated future are the three key phases of user experience process. And, in the light of reviewed literature, user experience process is divided into two parallel layers, which are meaning and functionality layers (Figure 4).

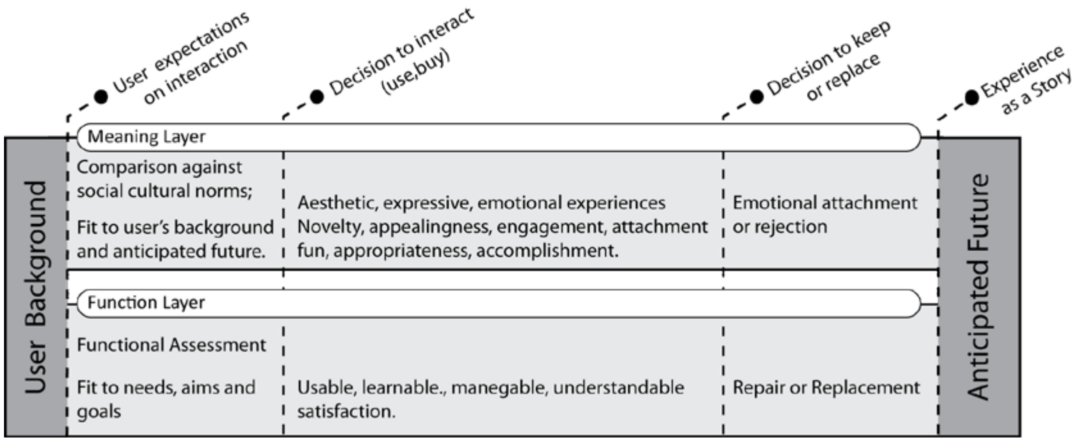


Figure 4 User experience process

Users assess the qualities of products from functional and meaning perspectives. Functional assessment of product includes product characteristics such as usable, learnable, easy to manage, understandable and degree of satisfaction from functional performance of the product. Whereas the meaning perspective includes the mental image of the product which deals with the assessment of aesthetic, expressive and emotional experiences with the qualities of novelty, appealingness, engagement, attachment, fun, appropriateness and sense of accomplishment.

The meaning and function layers (Figure 4) are not clearly separated from each other as a good functioning product might lead to a degree of attachment as well as a stylistic but poorly functioning product. Evaluating smart products for the qualities of function layer requires conventional metrics of usability evaluation; efficiency, effectiveness and satisfaction (ISO, 2002), whereas meaning layer requires different metrics and measures, such as; *interaction, attention, adoption, trust, invisibility, impact and conceptual models* (Scholtz & Consolvo, 2004).

There are different approaches to the metrics, measures and qualities of user experiences to evaluate interactions with smart products. For example, Hassenzahl (2004a) identifies three main attributes of products that should be studied for good interaction design; *pragmatic attributes, hedonic attributes* and *evocation*. According to him pragmatic attributes are related to the instrumental needs of users for manipulating the environment, hedonic attributes stands for personal improvement and identification of self among others and evocation is for stimulating memories, remembering and sharing experiences. In an another example, Swallow, et al. (2005) identified 5 major properties of products that mediate user experiences; *identity, sociability, security, organization and relevance*. According to them a product should be able to express symbolic values related to its user, facilitate social interactions, provide a sense of security during use, help organize daily routine and be relevant to instrumental needs of users.

Both Hassenzahl (2004a) and Swallow et al. (2005) emphasized that a successful product should satisfy instrumental, self representation and self identification needs during the interaction with the product. Observing and evaluating the degree of satisfaction of these needs pose novel requirements to data collection methodologies. In correspondence to this approach Battarbee, et al. (2008) proposed that a user research study should be designed with the following principles in mind;

- *Social setting,* studies should be carried out in natural use setting not in laboratory with representative users.
- *Application of several methods,* research methods should allow users to express their own ways of interaction and research methods and tools should be unobtrusive,
- *Openness,* designers should let different interaction modalities with the product as that's users who will make sense of the interaction and create a meaning out of it.
- *Appropriate study time,* the study should be long enough (a few weeks) to observe variations in interaction
- *Chains of actions,* actions and events sequence of occurrences should be studied in context.

With a human centered approach, Isomursu, et al. (2007) evaluated data collection methods from two perspectives; user's and designer's perspective. From user perspective, data collection methods should fit into the use and users should be able to express their experiences, methods should be usable and easy to apply, the method and data collection tools should not interfere with the user experience and the use context. From designer's perspective, they argue that data collection methods should inform and provide data for design process, easy to interpret and be valid and reliable (Isomursu, et al., 2007).

The reviewed literature suggests that;

- User research studies should be designed to collect information on instrumental, self representation and social needs of users.
- User experience studies should be conducted in natural settings for longer study durations.
- Several data collection methods should be applied for reliable and valid results.
- Data collection procedure should not interfere with users' everyday life and should not affect the user experiences.
- User research studies should be flexible enough to aid users in expressing themselves during the studies.

User research studies of smart products for both function and meaning layers (Figure 4) requires in context observation as a consequence of product characteristics (see 3.2.1) and social (see 3.2.2) and physical contextual factors (see 3.2.3). Data Collection for the functional assessment of products and activities in natural environments can be achieved with a task centric approach as the beginning and completion of tasks and activities are definite. Data collection equipment which is composed of simple sensors and data loggers can be customized to capture predefined repetitive events in domestic environments. Evaluating the functional layer of user experiences requires a detailed observation of second phase of the user experience process which starts with decision to use and ends with decision to replace. Consequently, evaluating function layer (Figure 4) of user experiences requires ethnographic methods. Digital ethnography (see 3.5.3.4) which combines technological tools and ethnographic methods might provide the necessary arsenal for the evaluation of utilization and usage of smart products.

On the other hand, observing users for the evaluation of meaning layer (Figure 4) requires a complete understanding of user experience process since users' background, socio-physical environment and anticipated future have effects on users' internal representation of user experience. Collecting data on users' subjective representation of user experience requires observation of everyday routines of users and their interactions with the environment, product and third parties in addition to information on users' background and anticipated future. Therefore evaluating meaning layer requires self reporting tools as well as ethnographic methods.

3.4. Data Collection Requirements of In-Context User Research Studies

Based on the reviewed literature, data collection requirements of in-context user research studies for the design and evaluation of smart products might be grouped under three main titles;

- **Product Characteristics;** The need to develop novel smart products and define their characteristics, functionalities, interaction styles and resulting use experiences require data collection on users' current everyday life and their unmet needs at natural use contexts.
    - Smart products are context aware, interacting both with their user(s) and other smart products, ubiquitously embedded into the environment, always on and have various interaction styles.
    - Smart products utilize built-in sensors and network connectivity to collect data for providing better user experiences. Exploiting this data provides additional information on user research studies.
- **Study Duration;** User experiences start, evolve and continue based on user background, contextual factors and anticipated future hence requires a thorough understanding of the process.
    - Observing smart products' integration with the socio-physical environment requires longer data collection durations.

- Evaluation of smart products requires understanding whole product life cycle instead of snapshot of use.
- User experience develops and iterates over time. Smart products collect and analyze information from the environment and their interactions with users. User experience with a smart product is not fixed, it iterates after each user interaction and communication with the environment.

- **Contextual factors;** In order to design products that blend into the social and physical context of everyday life, data on contextual factors should be collected.
  - *Ethnographic methods of social sciences needs to be adapted for data collection:* Methods of ethnography might be useful for in-context data collection requirements; however those methods have to be modified to meet the needs of new product development processes as they require larger number of participants and shorter study durations.
  - *Observing routine mundane activities and identifying needs and problems for product development is essential:* Designers and developers of smart products are usually detached from real users and contexts of use. In-depth data on certain activities are necessary for informing design decisions.
  - *The presence of evaluators in a user experience study in natural environments must be kept at minimum:* Studies conducted in real use contexts such as user's home, limits evaluators presence and role in the study. Observing users for longer periods of time at their own environments requires unobtrusive data collection tools.

3.5. Data Collection in Domestic Environments

Smart products provide an array of functionalities that mediate education, work, health-care and entertainment activities as well as mundane everyday activities such as shopping, eating, cleaning, sleeping and grooming at domestic environments.

The differences between users' and designers' conceptualization of everyday activities into products are significant for smart products (Chamorro-Koc, Popovic, & Emmison,

2008) as designers and developers tend to create technology driven products whereas users seek pleasant experiences. Establishing a common ground between users and designers requires studying people at domestic environments to understand user behavior in certain contextual situations. Product development studies in contextual environments have strong roots in HCI and there are continuous efforts to explain the interaction between the user, environment and the artifact by studying user needs, expectations and preferences, effects of contextual factors and the characteristics of smart products.

3.5.1. Characteristics of Domestic Environments

Domestic environments serve as a private place for their residents as well as a social place for their visitors. The domestic environment is shaped based on the needs and preferences of its residents and treated as a home. Although the home is shaped by its residents, the activities and the scheduling of these activities are tightly coupled with other people living inside or outside the home. For example, an adult's life is shaped by the institutions he or she is a member of or the people he or she is responsible for or caring for. Additionally, the physical characteristics of built environment, goods, furniture and devices inside the house define how people spent their time inside the house.

How people use their time in domestic environments has been an active area of research since 1950's with the introduction of home technologies such as Television. Diaries and surveys are among the popular data collection tools for understanding the time use in domestic environments (Frohlich & Kraut, 2003). Utilizing standardized activities to understand time use is a common method for coding time use in domestic environments.

Time diary studies in which the house participants fill diaries on regular time intervals revealed that there are patterns of activities among specific groups of population (Robinson & Godbey, 1997). These patterns demonstrate four major activities in domestic life of American adults, which are sleep, personal maintenance, work and recreation. Moreover, the studies suggest that routine activities have a 24 hour recurring period because of the social, physical and physiological constraints. Daily activities are routine in weekdays of working adults and shows variations in weekends. Moreover, activities of daily life show more variations in adults living with children or pets. The social circle and the physical conditions also have effects on the everyday life of house residents as the activities inside or outside the house are planned based on these factors.

With social, individual, functional and emotional requirements for communication, entertainment, education, recreation, work, self-care and self representation; the home has been the target for an array of studies for the development of domestic smart products or the development of comprehensive solutions to achieve smart homes. Comprehensive reviews on smart homes and domestic smart products can be found elsewhere (Harper, 2003; Meyer & Rakotonirainy, 2003; Taylor, et al., 2007; Venkatesh, et al., 2001). Hence, this study focuses on the characteristics of domestic environments for the data collection purposes in user research studies. The characteristics that are prominent for data collection are specified as;

- *Home is private;* Certain activities and spaces are private to the residents, collecting specific types of data (for example video) might be inappropriate for those activities and spaces.
- *Home is social;* Activities and schedules of residents are affected by other individuals and institutions, data collection must monitor not only the house but also the social context that it operates within.
- *Every home is different;* Although there are common physical properties of houses such as number of rooms and their functions, domestics environments are shaped by the needs and preferences of their residents. The physical properties, architectural plan, interior design and furniture content require customizable data collection tools.
- *Domestic environments have their own routine;* Domestic life has routine activities based on the responsibilities, needs and preferences of house residents. Conducting data collection studies within this routine require advance planning and logistics efforts to match research time plan to the domestic routine.
- *Activities are distributed over time and place in domestic environments;* Activities in domestic environments can be carried out both individually or as a group. Moreover, house residents might conduct activities simultaneously. To have a complete observation of a particular activity observing the complete domestic environment might be necessary.

3.5.2. Challenges Related to Data Collection in Domestic Environments

Given the characteristics of domestic environments, smart products and user research studies challenges related to data collection in domestic environments are listed under three main titles; privacy, customization and logistics & management.

3.5.2.1. Privacy

Residents at domestic environments need to feel comfortable, protected and secure in their personal spaces. Collecting data from these personal spaces raise issues of privacy, informed consent and discretion of private life. However, it is necessary for the evaluation and development of smart products in domestic environments (See Section 2.2). Smart products aim to provide pleasant user experiences by collecting private information, such as identity, location, user preferences, activities and social relationships. This private information is most of the time indispensable for the seamless delivery of customized services. Consequently, designing and evaluating smart products is highly dependent on this sensitive data.

Domestic spaces are divided into rooms based on their functions; hence different rooms have different privacy sensitivities. For example audio video recording in living room might be acceptable but it will likely to be rejected in bathroom. Collecting data at different fidelities at different locations might ease the privacy concerns. Meyer and Rakotonirainy (2003) propose utilizing non imaging simple sensors for certain activities and spaces to decrease the privacy concerns of residents. The downside for this might be the increased number of sensors in the environment. Consequently, house residents might feel that their houses are polluted with a lot of small data collection equipment. Additionally, the difficulties in handling and maintenance of increased number and type of devices for the data collection create management issues for data collection.

Another privacy concern that causes discomfort for everyday life of house residents is the feeling of being evaluated and the invasion of physical environment by researchers. For example, in a series of studies conducted in real home environments with a wide variety of sensors (cameras, microphones, object use sensors, state-change sensors, user position tracking, motion tracking, wearable accelerometers and an experience sampling tool querying user activities) Beaudin, Intille & Tapia (2004) reported that large number of sensors installed in the physical environment caused discomfort as a feeling of *"being judged and invaded"*.

It is argued that privacy concerns are related to having control over personal data (Ackerman, Darrell, & Weitzner, 2001). A popular approach to handle privacy concerns of house residents is to inform them for the nature of data collection, what is being recorded, what will be done with the data and the means for protecting their privacy. Meyer and Rakotonirainy (2003) report that giving users the power and consciousness over their personal information might reduce the perceived privacy threat. However, keeping track of what information is collected by which application creates a cognitive load for users and users get used to even video recording after a short period of time.

Aside from other data modalities such as diaries, activity logs and audio recordings, video data is the most challenging data modality for privacy handling. User research studies are highly dependent on video data for the observation of daily activities, hence there are a number of ethical issues related to the capture, evaluation, presentation and sharing of video data (Mackay, 1995). Users commonly give consent to the researcher for the utilization of video solely for research purposes and to be only watched by the researchers. Hence special care must be taken when playing the video clips to an audience and any information that might reveal study participants' identity must be removed from the video data.

There are guidelines and best practices for the handling of digital private data. World Wide Web Consortium releases privacy preferences for online web pages for setting general standards for Internet (Cranor, Langheinrich, Marchiori, & Reagle, 2002). In an another set of privacy guidelines, United States Federal Trade Commission (UFC) listed four main titles (US Federal Trade Commission, 2000) for the handling of private data, these four titles can be summarized as follows;

- *Notice:* User should be informed on what is collected and who else will have access to the data other than the researcher.
- *Choice:* User should have the freedom to stop data collection
- *Access:* User should have access to the collected data and edit the data set according to his or her will.
- *Security:* the researcher must take necessary measures to protect data from unauthorized access.

In summary; giving detailed information and control over data collection procedure to the study participant, avoiding the capture of certain data modalities in sensitive spaces and utilizing data collection tools that are able to blend into the fabric of domestic environment might be three possible solutions to privacy issues related to data collection in domestic environments.

3.5.2.2. Customization

Domestic environments mediate an array of activities over different physical spaces. Usually these activities take place simultaneously and observing these activities in their real context requires data collection tools distributed all over the domestic environment. As each domestic environment is different, data collection tools need to be customized according to local physical and social conditions.

Data collection tools must be designed to fit into domestic environments in general, additionally they need to snap on a wide variety of objects with different surface qualities in individual domestic environments (Tapia, et al., 2006). For example, data collection equipment needs to have details which will allow them to be attached onto and removed from any surface easily and without leaving any traces on the surface to protect house residents' property. Additionally, having an easy to customize data collection tool leads to shorter set up times for data collection and might lead to longer data collection durations.

Data collection tools must be invisible to the house residents so as not to have effects on the activity that is carried on. Activity theory suggests that tools that are utilized to measure or observe activities have potential risks of altering the activity that is observed, correspondingly, the activity itself also has the potential to transform the data collection tool (Kuutti, 1995). Therefore, data collection tools must be customizable to be invisible to the user, blend into the environment and to be neutral in the data collection process. Additionally, data collection tools must be customizable to the user preferences in terms of privacy and control. House residents should be able to control what information is collected, when it is collected, from which space it is collected. Data collection tools should provide the versatility and modularity to fit in the physical requirements of domestic environment and user requirements based on privacy preferences.

Moreover, physical context in each data collection site is different and data collection tools also need to be customized to the actual socio-physical environment. For example ambient audio noise levels might show variations in each site and if present, microphones should be adjusted to capture best possible sound quality. Another example is the customization of context triggered data collection. When contextual factors such as vibrations are used as a trigger for data collection, vibration characteristics of the environment (large machinery working at the street, vibrating domestic equipment, maintenance in the building, noisy elevator etc.) must be observed and the threshold for triggering activities must be customized accordingly.

In summary, customization of data collection tools can be grouped under 4 main areas. Data collection tools must be customizable to;

- *Domestic environments;* data collection tools must not deform private property
- *User preferences*; users might prefer to stop recording certain data modalities at certain spaces or times.
- *Activity characteristics;* data collection tools must be neutral to the activity.
- *Contextual factors;* data collection tools must permit a standardized rate of sensitivity to contextual factors.

3.5.2.3. Logistics & Management

It is possible to conduct simultaneous data collection studies in distributed geographical locations with hundreds of data collection devices in each site; however the transfer and implementation of these devices to the study sites, customizing, monitoring and removing them from the site are major requirements for data collection. Therefore, designing, implementing and maintaining multi site studies require advanced planning of logistics.

User schedules in domestic environments are usually shaped by external factors such as work, children's schedules and interactions in social circle; hence users have limited time to allocate for home visits for user studies. In order not to intrude users' everyday life number and duration of home visits should be kept at minimum.

Installation and customization of data collection tools require at least two home visits. At the first visit, assessment of the physical environment and participants' preferences for data collection should be completed. Based on this assessment data collection tools should be installed and customized in the second visit.

Logistics and maintenance of data collection tools impose certain form factors and weight limits to the tools. Data collection devices must be robust and resistant to impacts;

however they should neither be heavy nor bulky. On the contrary, small form factors such as “smart dust” (Kahn, Katz, & Pister, 1999) are also problematic as they are almost invisible to the naked eye and decreases participants control over data collection.

Moreover, synchronization of different data collection tools is essential for simultaneous data collection with various devices. Therefore, the technological context of domestic environment should be reviewed prior to study.

To sum up, logistics and management requirements of data collection studies can be listed as follows;

- *Plan in advance;* Data collection at multiple sites requires careful planning
- *Assess the sites;* Data collection sites must be assessed in terms of transportation, physical characteristics, technical infrastructure and participant schedules.
- *Monitor data collection;* in order to minimize site visits the data and data collection tools should be monitored remotely.

3.5.3. Data Collection Methods in Domestic Environments

Various data collection tools and methods are available for user researchers. Some of these tools and techniques are better for particular aims, products and environments. Deciding on a particular data collection methodology for a given user research study requires identification of factors that determine the best data collection methodology. Six factors are identified for determining the best suitable data collection methodology in social sciences (Kalof, Dan, & Dietz, 2008), which are;

- *The type of study;* qualitative or quantitative,
- *Sampling;* probability or non probability,
- *Subject of study;* individual, a group, culture or nation
- *Researcher preferences,*
- *Time frame of the research study,*
- *Financial Costs.*

Data collection methodologies for social sciences are shaped by the above mentioned 6 general factors; these factors can guide researchers for the selection of suitable data collection tools and methods. Although, tools and methods of data collection is selected based on the tradeoffs among these factors, generally a combination of data collection methods are utilized to answer research questions. As domestic environments and smart products pose novel challenges for user researchers utilizing an assortment of methods to achieve a wider perspective is essential.

Given the requirements of smart product development studies in domestic environments and the factors of data collection methodologies in social sciences; data collection methodologies in domestic environments are grouped under 4 main titles; *surveys, self report tools, ethnographic methods and digital ethnography.*

3.5.3.1. Surveys

Surveys are one of the most common data collection techniques of social sciences. For user research purposes surveys can be administered both in the form of questionnaires and interviews. They can be utilized at any phase of the study for various purposes such as understanding participant background, evaluating the interaction, collecting the reflections of user experience on anticipated future and informing design decisions.

Questionnaires are cost effective data collection tools that generate quantitative results. They can be prepared and distributed rapidly. However, they are termed as quick and dirty data collection tools for user research, since the wording and layout of the questionnaire items and respondents' familiarity to the subject matter have effects on the responses (Rubin, et al., 2008). There are standardized questionnaires for usability assessment of software artifacts (Folmer & Bosch, 2004); however, there is no standardized questionnaire for the user experience evaluation of smart product in domestic environments.

Instead of being the primary source of data collection, questionnaires act as a complementary data source for understanding usage in context (Charlton & O'Brien, 2002). Questionnaires are usually administered before the actual user observation starts. Participants are expected to complete questionnaires on their own, consequently delivering the questionnaires, expecting participants to respond them and collecting them back might disturb participants and data collection environment. Hence, interviews might suit better for data collection during and after the user research study.

Interviews are very effective in collecting subjective representations of user experiences. They can be utilized for assessing user requirements, quality of experience or future expectations from smart products. Interviews can range from completely unstructured to structured ones based on the goal of the study. Structured interviews may generate quantifiable results, whereas unstructured interviews collect subjective information with open ended questions. An interview with mostly open ended questions can reveal participants' perception and representation of user experiences (Kalof, et al., 2008).

Interviews are heavily utilized in usability and user experience research studies as data collection tools. Moreover, special applications of interviews based on the number of participants, subject of the study and the environment in which the interviews are conducted are available for user researchers. Focus groups and in-depth interviewing are two of these special applications of interview studies.

Focus groups are moderated by a researcher to collect participants' background, understanding and reflection on a particular topic. They produce qualitative data on participants' perception of the subject matter. They are usually conducted in special rooms and detached from the actual context and the activity or the product (Rubin, et al., 2008). On the other hand in-depth interviewing is usually conducted face to face with one correspondent with the aim of creating a detailed image of participants' background, behavior patterns and expectations. Interviews often do not lead to quantitative results, whereas they are utilized to collect a qualitative assessment of participant standpoint on a particular subject.

Although surveys seem easy to administer, developing a reliable survey for user studies require validation of each survey item for their accuracy in measuring the target concept (Kalof, et al., 2008). Even though survey items are valid measures of user research, both questionnaires and interviews are vulnerable to selective recall, report and evaluator performance errors (Charlton & O'Brien, 2002). Participants' capability to observe their environment varies based on their ability to remember and report, consequently they tend to distort what really happened while they are recalling and reporting to the researchers. In addition to recall and report errors, participants usually modify their responses to interviews to portray a socially acceptable profile. Besides participants capability to report their experiences, interviewers' ability to take notes and interpret participants' comments are highly influential on the results of survey data.

3.5.3.2. Self Report Tools

Self report tools and ethnographic methods address recall and report issues of surveys by collecting the data at the moment it emerges. They are utilized to collect data from the participants with their own efforts based on a schedule or activity without the presence of a researcher with minimum intrusion to participants' environments. Self report tools can be utilized for collecting a subjective evaluation of an activity or product as well as for inspiring the design process by motivating the users to take notes of their surroundings. Diary keeping, experience sampling and probe studies are prominent applications of data collection with self report tools. However, self reporting is by definition, highly subjective and requires additional data sources such as direct observation to create an objective understanding of the self reported situations.

Diary Keeping

In diary keeping, participants are asked to document their activities on a particular frequency or after certain triggering event. Diaries can vary from unstructured to highly structured ones with tasks and questions (Palen & Salzman, 2002). Utilizing a time diary minimizes the recall / report errors and provides a detailed account of user activities (Hulkko, et al., 2004). Although they have an evident advantage, frequent data collection intervals might be burdensome for the participants, the data is highly subjective and often leads to missing information (S. Intille et al., 2003). Providing data collection devices such as cameras, video cameras, sound recorders, smart phones might relieve the burden of writing down diary entries. Although the term diary keeping implies a written form of recording, voice mails (Palen & Salzman, 2002), still images (B. A. T. Brown, Sellen, & O'Hara, 2000) and video recordings (Ylirisku & Buur, 2007), can all serve as a means for recording daily activities and participants' perception of these activities.

Brown et al. (2000) asked their subjects to capture moments of their everyday life as a visual diary and interviewed three times a week to collect subjective assessment of particular moments that are significant to their subjects and found that capturing still images are less burdensome than writing down diary entries and less likely to generate missing data.

Ylirisku and Buur (2007) report that utilizing a video diary has prominent advantages such as providing visual access to personal private environment and difficult to observe situations; additionally, video diaries provide visual data on prolonged activities that take several weeks to observe without invading natural environments.

Palen and Salzman (2002) utilized a voice mail line to collect participants' experiences with a mobile phone and reported that voice mail entries gave them a sense of their participants' activities through a typical day and help them to construct customized interviews for their participants.

Probes

Diary keeping is effective tool for recording data at the time it emerges, however converting diary data to influence design decisions or evaluate products requires additional information such as contextual data and participant aims, goals and expectations. In order to collect this data contextual environments are probed with special packages of self report tools.

Hutchinson et al. (2003) defined probe simply as "*an instrument deployed to find out about the unknown*". In a similar definition Mattelmäki (2005), defined probe as "*design–oriented user research toolkits that are based on self documentation"*. The definitions are very general and anything installed in context and some data recording capability can be named as a probe. In order to clarify the probes approach 5 features of probes; *functional, flexible, usable, enables logging and supports design phase* were identified by Hutchinson et al. (2003).

The aim of the probes, although they are customizable, are to observe and record the technology use over time and collect information about the users, to field test the technology, to watch and inspire ideas by provoking the users to reflect on and verbalize their experiences, feelings and attitudes, to visualize their actions and contexts and to inspire designers for the realization of new technologies (Hutchinson et al. 2003).

Similarly, Mattelmäki (2005) identified four characteristics of probes based on the aim of the research studies. First, probes should be design oriented and facilitate designers' creative thinking. Second, probes should act in users' subjective world and find information about users, their experiences and their internal goals. Third, probes should enable active user participation as they are based on self documentation. Fourth, probes should create a direct interaction between the users and designers.

Probes studies were carried out with 'probes kits' which might be technological instruments such as video recording and messaging tools as well as traditional media such as postcards. Probes might also contain tasks for users to reflect their understanding of target activities and interactions such as taking photographs or videos. Novel applications of probes approach include utilization of social networking applications such as Facebook and Twitter to collect data online over several weeks without distribution of physical materials (André, Schraefel, Dix, & White, 2011).

Probes are effective tools in collecting participant's perception and providing information that can influence design decisions (Hutchinson et al. 2003). However they still require additional data sources to clarify and understand the meaning of participant's perception of the situation and the context.

Critical Incident Reporting

Critical incident reporting (originally *user-reported critical incident method)* (Castillo, Hartson, & Hix, 1998) has been utilized to collect data on critical events in remote usability studies. In critical incident reporting researchers are not present in context and study participants are expected to report predefined events as critical incidents with necessary information. Today critical incident reporting for software tools is very common and automatic. Many software packages automatically collect data on critical incidents and ask for reporting after a system crash. Although the mainstream utilization of critical incident reporting is automatic, it can be utilized as a self report tool. The major drawback of critical incident reporting by study participants is the need for training and instructing study participants for identification and proper reporting of critical incidents.

Even though critical incident reporting is utilized mainly for software tools, subject to recall errors and might interfere with the activities conducted in the domestic environment, it may be effective on collecting users' perspective and semi structured subjective representation of user experience (Castillo, et al., 1998).

Experience Sampling Method

Experience sampling method (ESM) has been utilized to collect data on time-use by notifying users at random or certain intervals to record their experiences (Larson & Csikszentmihalyi, 1983). Participants are provided with a notifying device either a cell phone, mobile computer or a simple stopwatch to remind them to "sample" their activities on a predefined schedule. Participants can synchronously report their samples with networked devices and can get immediate feedback and custom inquiries relevant to their actual experiences. With this interactive data collection capability ESM is less prone to recall and report errors. Researchers can configure ESM tool to ask questions after specific events and specific responses. However, short sampling intervals and increased number of questions to the participants might be burdensome and might have adverse effects on the data.

In order to minimize sampling rates and burden to the participants a context aware ESM tool is proposed (S. Intille, Rondoni, Kukla, Iacono, & Bao, 2003). The tool collects data with the attached sensors and identifies user activities with the help of a software and asks questions to the participants whenever certain activities are triggered. With increased accessibility to mobile internet connection and ultra mobile personal computers such as tablets and smart phones, experience sampling can be extended to virtually any environment and can be applied to various activities. However, there is always a tool that demands participant's attention which might be disturbing for longer study durations.

3.5.3.3. Ethnographic Methods

Modern ethnography has its roots in the early years of 20^{th} century with Bronislaw Malinowski's study in the Trobriand Islands during World War I. Since then ethnography has become a popular method for observing social life of groups of people. In social sciences, the duration of an ethnographic study might range from a couple of months to a few years. However, in HCI new product development cycles are so short that direct application of ethnographic methods is almost impossible. As observing activities, understanding goals and anticipating needs of users are critical for the development of successful smart products, applications and adaptations of ethnographic methods in user research studies in the context of daily life is widely discussed in the literature (Nardi, 1995; Rose, et al., 1995; Siegel & Dray, 2005; Simonsen & Kensing, 1997).

In classical ethnographic studies activities and daily routines of social groups are observed and documented by ethnographers who are blended in the group. In Rose et al. (1995), Hammerslay and Atkinson (1983) defined ethnographers' role as "*participating overtly and covertly, in people's daily lives for an extended period of time, watching what happens, listening to what is said, asking questions (p115)*". Traditional ethnographers immerse themselves into the culture that is being observed for weeks or months but product development processes cannot allocate time periods in that scale for observation. There is constant effort to speed up the observations in context without sacrificing the contextual information in product development process.

Rose, Shneiderman & Plaisant (1995) provides a general framework for the application of ethnographic methods on the evaluation of software user interfaces. They state that traditional ethnographic studies usually take weeks to months; however user interface designers need to utilize an applied ethnographic method in which observation duration is limited to days or even hours. For example, Millen (2000) introduced “rapid ethnography” which is a compilation of field research methods to understand users and their daily routine in a reasonable time slot in an ongoing design process. Millen (2000) reported that limiting and directing the study objectives, collecting data with several observers, observing virtual activities of informants as well as direct observation in context, and joint evaluation of qualitative data shortened the duration of ethnographic study. Additionally, he concluded that utilizing rapid ethnography shortened the time to generate behavior models.

The need to adapt ethnography to the new product development process and user studies forced scholars and practitioners to refine ethnographic methods for understanding interactions among users and products. There are both methodological and technological approaches for the alterations of ethnographic methods. Nardi (1995) approached ethnography from activity theory perspective and tried to classify and categorize contextual situations so as to predict, identify and analyze routine ones. Furthermore, Nardi identified 4 methodological implications of activity theory to observe context (using Nardi’s (1995) words);

- *A research time frame long enough to understand users’ objectives*
- *Attention to broad patterns of activity rather than narrow episodic fragments*
- *The use of varied set of data collection techniques including interviews, observations, video and historical material without undue reliance on single method*
- *A commitment to understand things from users’ points of view. (Nardi, 1995, p. 47)*

These implications of activity theory on ethnography suggests that the duration of ethnographic studies should be long enough to cover complete user experience to reveal patterns and routines of use. Moreover, complete understanding of the context, activity patterns, interactions and user experience require utilization of multimodal data collection techniques in which collecting user needs and expectations are crucial.

The successful blend of environment and product to ensure the efficient and hassle-free user product interaction requires a thorough understanding of the environment. For example in Labscape (Consolvo, et al., 2002) various quantitative and qualitative user study methods have been utilized to evaluate a software application for cell biology laboratories. It is found out that traditional usability testing is not sufficient for evaluating applications that require physical displacement and a variety of conditions. In Labscape study, Lag Sequential Analysis method, which is generally utilized in psychology and anthropology has been used and reported as effective for evaluating ubiquitous computing applications. Lag Sequential analysis generates quantitative data from the observation of everyday routine of users during a regular day. Observation on natural environments are coded based on predefined activities and the frequency, duration and pattern of activities are analyzed for user experience evaluation (Consolvo, et al., 2002)

Contextual inquiry is another common application of ethnographic studies in which users and researchers engage in a dialogue on everyday activities to reveal user needs and expectations. Users perform routine activities and researchers ask in-depth questions to inform designers and evaluate products. In contextual inquiry researchers observe snapshots of use and try to collect data on subjective representations of these snapshots on user side (Wright & McCarthy, 2010). The main downside of contextual inquiry is the presence of evaluator(s) at context during the study, which limits the utilization of contextual inquiry in domestic environments.

Dourish (2006) states that ethnographic methods restored users' role from a passive recipient of technology to active participators of design process by expressing their needs, expectations, everyday use and adaptation of technology in user studies. He adds that ethnography also provides information not only on the individual use of technology but also on the social meaning of interaction, which might provide information on the contextual environment.

In order to strengthen users' role in ethnographic studies without adding extra burden to their everyday routine, technological tools such as mobile computers, sensors and networking technologies are heavily utilized in ethnographic studies conducted in domestic environments.

3.5.3.4. Digital Ethnography

Making a detailed observation of people's everyday activities without the presence of human observers and invading their environment is a major challenge for user experience researchers. There are two significant responses to this challenge; one of them is building highly instrumented environments for participants to move in and live for the duration of the study and the other is the utilization of technological tools in participants' own environments to collect data.

Instrumented environments are experimental houses accommodating advanced sensing and recording facilities to collect, organize and evaluate data on everyday life of users. The Aware Home (Kidd, et al., 1999), PlaceLab (Stephen S Intille, et al., 2006) and Philips HomeLab (Ruyter & Aarts, 2004) projects are the examples of experimental houses for studying people, activities of daily life and interaction with the smart technologies. Those laboratories provide a closer setting to natural home environments than traditional usability laboratories. Besides recording inhabitants' daily life PlaceLab and Aware Home utilizes algorithms for inferring activities and labeling them automatically for data visualization. In PlaceLab and Aware Home, study participants are observed with technological tools, such as audio/video recordings and sensor networks. For example, Place Lab is instrumented with computers, a wide array of sensors and audio/video recording capabilities is used to observe users daily routine for days or weeks as users treat Place Lab as their temporary home (Stephen S Intille, et al., 2006). The downside of live-in laboratories is the financial costs associated with them, hence they are extremely expensive to set up, manage and maintain also they are not flexible enough to accommodate different research set ups.

The second approach, instrumenting participants' own environments with data collection tools; promise novel opportunities for ethnographic observation of domestic environments. Distributed and implicit input & output and natural physical interaction with computation in domestic environments are difficult to keep track of with direct observations; however automatically generated logs of interaction and contextual data stored in the system could provide valuable insights on the user experience evaluation of smart products. For example, Philipose et al. (2004) instrumented one of the authors house with radio frequency-identification (RFID) tags and asked study participants to conduct some of the activities from a list of 14 activities. Their inference engine PROACT was successfully predicted 88 percent of the time, whether a particular activity occurred or not.

In another example, Morris et al. (2003) utilized ethnographic methods and tried to immerse themselves into elders' daily routine. Within the light of this ethnographic study they developed experience prototypes to ubiquitously support the healthy aging of elderly people. Extensive array of technological tools, such as RFID tags, touch, pressure and other sensors as well as face recognition and activity recognition has been utilized in experience prototypes. A similar approach; utilizing handheld devices or embedded sensors for data collection has been utilized for a couple of studies (S. Intille, J. Rondoni, et al., 2003; Philipose, et al., 2004; Tapia, et al., 2006).

From a methodological point of view the next step for collecting user data in domestic environments would be collecting data automatically with the tool under study. Although this approach is relatively new it has been applied in a number of studies (Isomursu, et al., 2007; Swallow, et al., 2005). Increased processing power of everyday and mobile objects and their various sensing capabilities (audio/video recording, accelerometers, light intensity sensors, proximity sensors etc.) make them eligible for data collection for improving their usability and user experience performance. Swallow, et al. (2005) collected user experiences evoked by a smart phone with the same smart phone under study. Participants used the voice recording function of the phone to report incidents at the point of emergence.

The most significant advantage of coupling the application under study with the data collection tool is the data collection tool is always available whenever interaction occurs; however there is the risk of confusion at user's side that the application and data collection tool might be perceived as one and the problems related to data collection tool might have effects on the experience with the application under study (Palen & Salzman, 2002).

Another important point to consider while utilizing the application or device under study to collect data is the *Media Equation* (Reeves & Nass, 1996), which results from user's giving personalities to computing devices and giving normalized positive answers to the device as they know that they are evaluating the same device (Isomursu, et al., 2007).

Many software artifacts collect aggregated use information and submit them to designers and developers automatically. This approach has been utilized for mainly bug fixes and improvement of performance at the machine level. However, collecting information for user research purposes with the physical or software artifact might provide novel insights on both the formative and evaluative sides of user research. Embedding a data collection module to ubiquitous devices or at least to the prototypes might lead researchers to novel opportunities as they will be available whenever interaction occurs, collect quantitative data and provide feedback linked to the context, user state and contextual factors.

The adoption of automatic data collection might lead to the representation of user interface and device specific activities in a digital format without the presence of a human observer. Hence, automatic data collection provides opportunities for decreasing the study duration, increasing the sample size and removing most of the study burden from participants, and minimizes privacy concerns.

Besides these opportunities, the application of digital ethnography raises a number of issues. The major one, as in many of the contextual studies is privacy. Greenberg (2001), Grudin (2001) and Masten and Plowman (2003) addressed the privacy issue and stated that privacy concerns should be tackled as they arise in each distinct context separately. Grudin (2001) takes the discussion one step further and addressed the digital representation of context from privacy perspective. In traditional ethnographic methods user data was recorded on physical tapes, papers etc. which made them harder to share. However, in digital media the sharing and transfer of the data is quite easy and open to abuse. Grudin states that;

> *"We are losing control and knowledge of the consequences of our actions, because of what we do is represented digitally, it can appear anywhere and at any time in the future. We no longer control access to anything we disclose."(Grudin, 2001 p279)*

Another issue addressed by Grudin (2001) is the partial digital representation of context in use environments. He argues that when the context is represented digitally, only a part of it can be captured, which can change the impression it makes or even gives wrong impression. In order to overcome this, extensive contextual information can be captured but this will, again, result in the raise of the privacy issue and complex data collection tools.

Digitally representing participant data and having the chance to consult a number of evaluators provide opportunities for research study designs; however conducting a digital ethnographic study requires utilization of advanced technological tools. The design, implementation, utilization and maintenance of these tools have remarkable financial and human resources costs. Sustaining and maintaining an advanced technical system requires constant attention of technical personnel for smooth and robust operation. For example; SenseCam (Nguyen et al., 2009) which ubiquitously records pictures of everyday life based on a certain schedule or triggering events such as sound, light or movement, requires hardware and software knowledge at researchers side and complete disclosure of participants everyday life. The privacy cost of utilizing SenseCam is significant for participants that most of them emphasized the issue.

3.5.4. Overview of Data Collection Methods and Domestic Environments

The three characteristics of domestic environments; privacy handling, customization of data collection tools and methods, logistics and management of data collection are key identifiers of data collection strategies. An overview of data collection methods compared to these identifiers is presented in Table 2.

Table 2 Overview of data collection methods in terms of characteristics of domestic environments

		Data Collection Requirements of Domestic Environments		
		Privacy	Customization	Logistics & Management
Surveys	Interviews	Extended durations intimidate participants.	Customizable to the product, participants and research study	Large N studies require researcher time and logistics planning.
	Questionnaire	Participant can anonymously respond to questionnaire	Standardized or customized to study objectives	Can be distributed easily with e-mail, WWW, phone and regular mail.
Self Report Tools	Diaries	Participants are in control of data	Customizable to the product, participants and research study	Can be distributed easily, digital versions need management.
	Probes			
	Experience Sampling method	High sample rates might intimidate participants	Customizable to the activities and contexts.	Requires management and monitoring of data collection
Ethnography	Direct Observation	Intimidating, applicable for short visits.	Customizable to the product, participants and research study	Large N studies require researcher time and logistics planning.
	Contextual Inquiry			
Digital Ethnography	Device Logs	Invisible and applicable for longer durations	Can only collect interface events and device state	Minimal logistics planning, requires management and monitoring of devices.
	Live-in Laboratories	Complete waiver of control over privacy.	Customizable to a limited degree.	No logistics considerations, requires management and monitoring.
	Portable Digital Data Collection Tools	Complete waiver of privacy, participants have control over data.	Customizable to the product, participants and research study	Requires increased logistics, monitoring and management efforts.

CHAPTER 4

METHODOLOGY

The proposed method is based on digital ethnography approach and aims to provide support on the selection, customization, deployment, monitoring and maintenance of data collection equipment.

The structure of the method is formulated based on the literature about in-context user research, ubiquitous computing and smart products and revised with respect to the results of two case studies. The case studies are conducted to observe different aspects of user research studies and data collection in domestic environments.

4.1. Assumptions

In the light of reviewed literature, it is assumed that;

- Utilizing customized data collection methodologies for user research studies might support ethnographic methods conducted in domestic environments.
- Standalone data collection equipment might minimize the presence of human observers in domestic environments.
- Utilizing data collection capabilities of smart products might assist their evaluations in context.
- Custom designed data collection studies for smart products might increase the affordability of user research in study participants' own environments.
- Characteristics of target use context have effects on data collection methodology.

4.2. Domestic Data Collection Method

Characteristics of domestic environments and smart products make it difficult to observe everyday life of users with a "one size fits all" data collection strategy. Hence, utilizing an

Table 2 demonstrates that surveys and self report tools are applicable when privacy concerns of study participants are high, whereas ethnographic methods are applicable when privacy thresholds are lower. Surveys can be distributed easily; however they lack the contextual information that is needed to interpret raw data and make sense of user responses. Ethnographic methods address the missing contextual data; however, data collection with the presence of researchers invades domestic environments and gives participants a sense of being evaluated and intimidation.

Live-in laboratories in which study participants' complete everyday life is recorded and evaluated, offer novel opportunities for data collection; however, they are not customizable to study participants' preferences, extremely expensive to build and maintain and require participants to move to a new place for the duration of the study. Consequently, portable data collection tools that mimic the capabilities of live-in laboratories which enable the observation of any domestic environment stand out as a major alternative. Although, the installation, monitoring, management and removal of these portable tools require expertise on hardware and software development, the capability to conduct simultaneous studies in multiple homes is a major gain for in context user studies.

With this general overview of data collection strategies of data collection in domestic environments the structure of a method for data collection in user research studies of smart products in domestic environments is presented in the following chapter.

adaptable, custom designed method for particular user studies stands out as an alternative to defining a generic data collection methodology. Moreover, utilization of customized equipment for each study design might also be an alternative to multi-purpose data collection equipment such as live-in laboratories which are over complicated, difficult to operate and expensive to maintain.

Previous work suggests that user experience evaluation process can be enriched by the application of ethnographic methods with the utilization of proper technological tools; however the combination of these tools and the formulation of data collection methodologies are still vague. The structure of a domestic data collection method is devised to observe application of technological tools in observing and capturing the daily activities of study participants and suggest a list of possible data collection strategies for a given research study. Domestic data collection method (Figure 6) aims to build a link between ethnographic methods and user research studies (Figure 5).

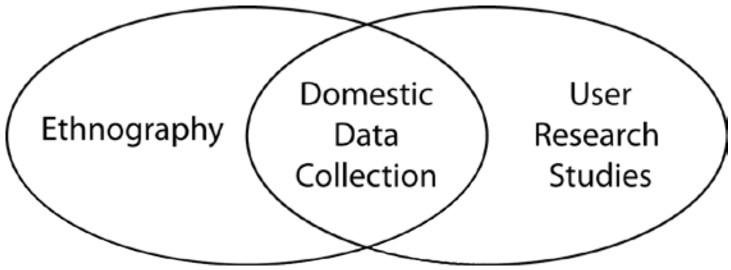


Figure 5 The relationship between ethnography and user research studies

Domestic data collection (DDC) method aims to guide user research studies conducted in domestic environments through the design, implementation and utilization of data collection equipment. User research studies conducted in controlled environments or contextual environments other than domestic environments are out of the scope of this study, hence DDC is not applicable to these studies. DDC method has two major phases which are linked to each other in an iterative nature. The first phase is preparation and the second is deployment of data collection tools.

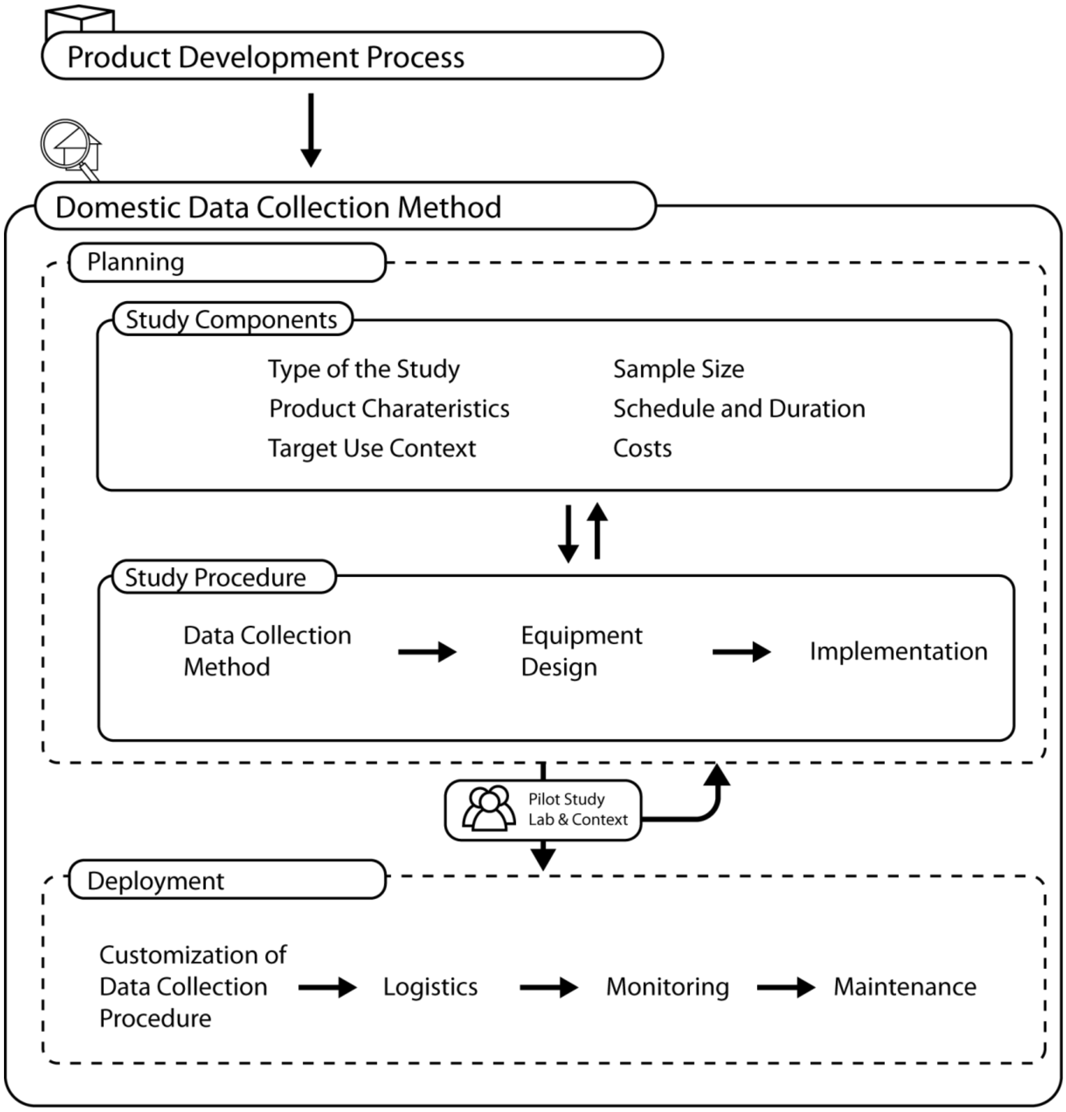


Figure 6 Domestic Data Collection Method Outline

In the preparation phase, the planning of data collection procedure with respect to the user research study components is completed. The literature review on smart products and data collection studies reveals six major variables that define the methodology of any given user study, the variables are specified as follows;

- Study type
- Product characteristics
- Properties of target use context
- Sample size
- Study duration and schedule
- Costs

The first three variables; type of the study (e.g. summative, formative), the product or activity under observation and the characteristics of target use context are independent of the data collection procedure. However, the latter three variables; sample size, the schedule and duration of the study and the costs associated with the study are dependent on the data collection tools and procedures. DDC method aims to define the independent variables based on the values of dependent variables and provide support on data collection procedure to satisfy the requirements of both dependent and independent variables. The variables of DDC define data sources, equipment design specifications and implementation strategy for data collection for a given data collection study.

Planning data collection and deploying data collection tools are the two major phases of domestic data collection method (Figure 7). In the first phase components of the study define the procedure of the study in which the data collection requirements, equipment design and implementation of data collection study are identified. The procedure then tested with pilot tests conducted both at the laboratory and in the real context of study. If the procedure satisfies the requirements in pilot tests the study advances into the second phase in which the data collection procedure is implemented in participants' own environments.

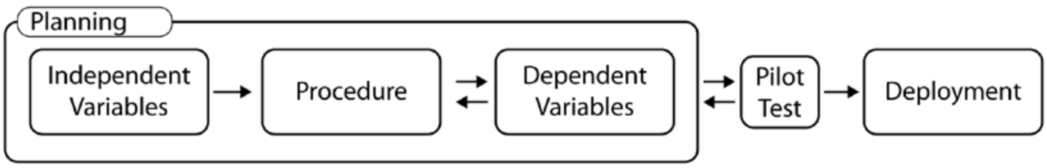


Figure 7 Overview of domestic data collection method

The three components of data collection procedure (Figure 8) are;

- Data collection method,
- Equipment design,
- Implementation of data collection.

They are identified by independent variables of user research study and they influence dependent variables accordingly.

The first component of procedure is data collection method. Data collection can be achieved by direct observations, participant self reports, sensor kits and/or with automatically generated device logs to represent daily routines of participants and their interactions with smart products.

The second component of study procedure is equipment design to meet the requirements of user research study. The equipment must be designed to fit in participants' home environment, should be set up, customized and removed with minimum effort and robust to operate in the field. Besides these requirements, data collection capabilities and physical properties of equipment are the key elements of equipment design. Sensing, storage, processing and networking capabilities of data collection equipment must fit into a physical form that is invisible to the user, activity and the user research study.

The third component of procedure; implementation of data collection procedure is a three phase process (Figure 8). In the preparation phase equipment is tested and customized to participants' environments. In the second phase the procedure for the transportation of human resources and equipment is shaped. Finally, in the third phase data collection is managed and monitored. Preparations for the removal of equipment are also conducted in this phase.

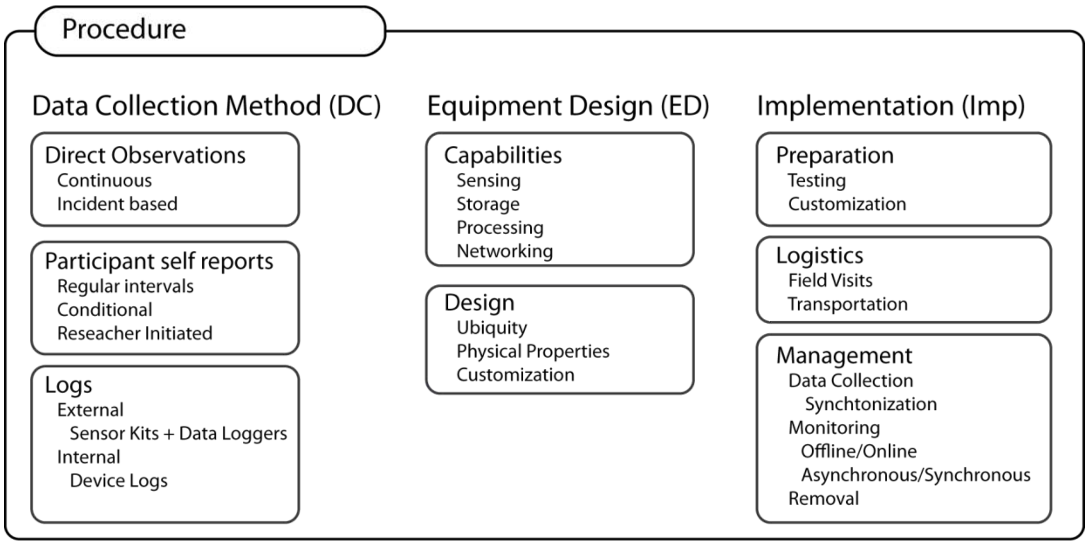


Figure 8 Components of data collection procedure

The deployment of data collection equipment into participants' houses is defined by study procedure and starts with customization of data collection procedure to the participants' own environments. The size of the house, possible locations for the equipment installation, clearances and logistic requirements need to be assessed and the equipment must be customized accordingly. After the customization, the tools need to be transferred to actual study sites hence logistics planning must be completed in the second phase of deployment. After the deployment actual data collection starts, therefore both the collected data and equipment must be monitored. After data collection, equipment must be removed from the site and maintenance tasks must be completed before the next deployment.

In the following sections phases of domestic data collection method will be presented in detail.

4.3. Independent Variables of Domestic Data Collection Method

Independent variables of domestic data collection method are the key elements that define data collection procedure. Independent variables define (1) *the type of study*; formative or summative, (2) *focus of the study*; observing needs or evaluating a smart product and (3) *the context of the study*; mobile, public, workplace or domestic environments.

Current study focuses on domestic environments; hence one of the independent variables; target use context is fixed to domestic environments. Additionally, the interactions among independent variables; the effects of product characteristics and context of use on the type of a user study or vice versa, are out of the scope of current study.

In the following sections, independent variables of domestic data collection method and the implications of these variables on the application of the method will discussed.

4.3.1. Type of the User Research Study

User research studies are divided into two general categories as formative and summative (Rubin, et al., 2008). Formative studies are generally conducted in exploratory phase of the design process as they are utilized to understand user thoughts, expectations, needs, anticipations, assumptions, habits, routines, experiences. Formative evaluations are usually employed to observe problem space for design directions. The output of formative evaluations can be both qualitative and quantitative, ranging from critical incident reporting, user comments gathering, in-depth interviewing to calculating efficiency and effectiveness of sample tasks (Bowman, et al., 2002). On the other hand, summative studies are generally conducted later in the design process when the product or concept is fully defined and a working prototype is at hand (Rubin, et al., 2008).

Summative and formative studies have both overlapping and diverging requirements on data collection procedures. While the former heavily utilizes participant self report tools and seeks in-depth data on the complete cycle of user experiences, the latter utilizes predefined success criteria and performance metrics for the evaluations of certain tasks. Both of the studies require collection of contextual data besides user data and minimum intrusion in users' daily routine and environment. The sample size for formative evaluations might be as low as one participant since it seeks the observation of high level concepts and thoughts, whereas the sample size for summative evaluations should be higher for statistical validity (Preece, Rogers, & Sharp, 2001).

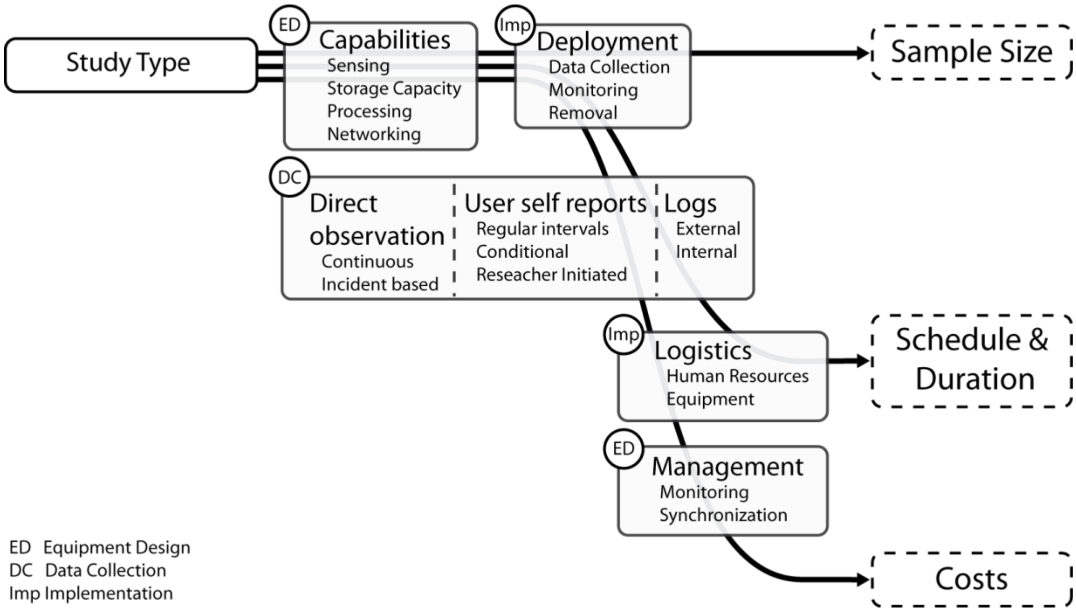


Figure 9 Implications of study type on dependent variables of data collection

Generally formative studies which are mainly focused on higher thought processes, routines, habits and activities of users in everyday life require direct observation and annotation of complete everyday routine of users for understanding the interactions with the objects and activities in the environment. Whereas, summative studies which are mainly focused on evaluation of a finished product, require the evaluation of interaction with a particular product or functionality against predefined criteria (Rubin, et al., 2008).

Figure 9 presents the anticipated implications of study type on dependent variables in terms equipment design (ED), data collection (DC) and implementation (Imp). Study type has direct effects on sample size, schedule/duration and costs associated with study in terms of data collection equipment capabilities and deployment procedure. Whether a study is summative or formative defines the technological features of equipment such as sensing, storage, processing and networking capabilities, which consequently defines deployment of these tools in domestic environments.

Whether to utilize direct observation, user self reports or automatically collected logs have effects on schedule and duration of the study and the costs associated with the study. Based on the study type, the study might be conducted early in the design process as a needs assessment or at the end of the study as a prototype evaluation; these options define the management and logistics of data collection equipment, as well as the costs associated with them. Utilizing direct observation without the presence of researchers in context requires high technology data collection equipment with management and monitoring activities, whereas logging interface events internally requires only a software update.

4.3.2. Product or Activity Characteristics

Smart products have various characteristics that present both opportunities and challenges for data collection (See Section 2.2). Similarly activities carried out in domestic environments exhibit broad variations based on frequency and place of occurrence, number of people involved, skills and tools required and previous experiences of participants in a particular activity.

Besides their information storage and processing capabilities smart products can be categorized according to three different aspects.

- Physical form factor
- Interaction modalities
- Functionality

Smart products were categorized as inch scale, foot scale and yard scale by Weiser (1991) according to their physical form factors. This categorization is usable for data collection procedures as it defines equipment specifications, area of observation and the schedule and duration for data collection.

Interaction modalities that are utilized for communicating users and the environment are the second aspect of smart products for categorization. Smart products interact with their users in various modalities, such as voice, touch, vision etc. (Jacob, et al., 2008) these interactions require data collection strategies such as interface events logging or direct observation or participant self reports.

Thirdly, the functionality of a smart product defines the frequency, location and duration of use. Whether a product is used for entertainment, education, communication, work or for routine daily activities define the social and physical context and describe different data collection strategies such as direct observation, participant self report, or complete recording of contextual environment and the interaction.

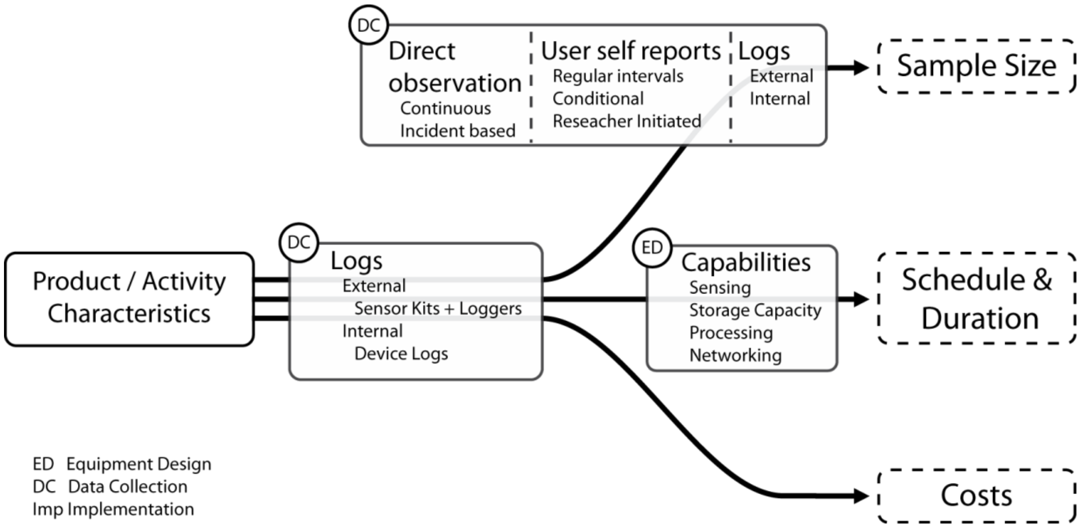


Figure 10 Implications of product and activity characteristics on dependent variables of data collection

It is assumed that characterizing smart products according to their physical form factors, interaction modalities and functionality, thus designing data collection studies accordingly identifies values related to sample size, schedule/duration and costs associated with data collection (Figure 10).

From activity observation perspective data collection is challenging that activities cannot be categorized with clear cut lines, activities can be conducted simultaneously or a single activity might continue for discrete time intervals. Nardi (1995) proposes activity theory to describe activities in terms of actions and operations. Decomposing activities into actions and operations identifies more specific requirements for user studies. Consequently, data collection efforts can be focused on a more defined set of requirements.

Data collection equipment can be customized according to the task analysis of small chunks of activities, actions or operations. Activities that rarely occur, ambient or unnoticeable in daily life can be overlooked by participants, however decomposing each activity in to smaller operations and customizing the data collection tool accordingly might provide a more efficient and thorough data collection procedure.

Besides composition of activities, the frequency and number of people involved in an activity might also have effects on the formulation of data collection study. The frequency of an activity affects the technical specifications of data collection equipment such as battery life, physical dimensions or robustness. And number of people involved in an activity identifies privacy handling challenges in data collection.

4.3.3. Target Use Context

Target use context, which is domestic environments for current study, has effects on data collection in terms of social and physical characteristics. Physical characteristics of domestic environments can be listed as; temperature, humidity, vibration, noise, light intensity, available space, presence of sensitive furniture, reflective walls etc, besides this list of physical factors, wireless internet connection and GSM coverage are among the physical factors that are related to infrastructure. On the other hand, social characteristics of domestic environments, such as presence of others and their age, gender, and relationship with the study participant are key points while considering privacy challenges in data collection.

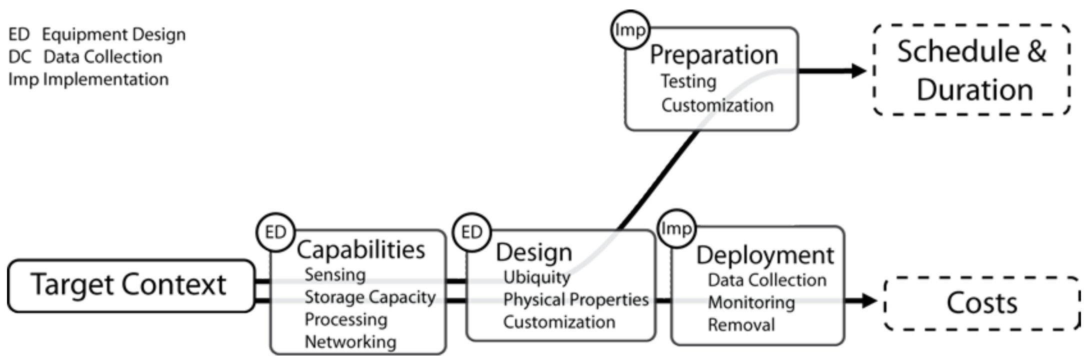


Figure 11 Implications of contextual factors on data collection

Social and physical characteristics of context are associated with costs in terms of design, technical capabilities and deployment procedure of data collection equipment (Figure 11).

Grasping complete information on the contextual factors and representing it digitally require heavy usage of sensors and data loggers, which in turn increase equipment costs. In addition to design and capabilities of data collection equipment, preparing them for the deployment in participants' environment might require careful preparation of equipment with testing and customization done both at the laboratory and at the context of use (Figure 11).

It is assumed that both physical and social properties of context should be observed before implementation of actual data collection procedure. Physical properties of context, might have result in partial or complete loss of data. Additionally, presence of other parties and their rejection of data collection might again result in loss of data. Participants' privacy concerns should be collected and protected accordingly; however, schedule and duration of guest visits cannot be anticipated.

4.4. Dependent Variables of Data Collection

The type of a study; summative or formative, subject and context of any given research study are generally set prior to research design. However, number of participants, duration of the study and costs associated with the study do not have clear answers prior to data collection planning. Customizing the sample size, schedule, duration and the costs, based on overall research objectives sets the study procedure and defines the data collection tools and methods. The tight schedules and budgets of new product development processes impose utilization of technological instruments for the observation of domestic environments in order to meet the requirements of user research objectives.

Planning the data collection procedure covers equipment design, procedural planning and implementation based on independent variables to define dependent variables for specific user research studies. The variables and possible values of domestic data collection method are presented in Figure 12.

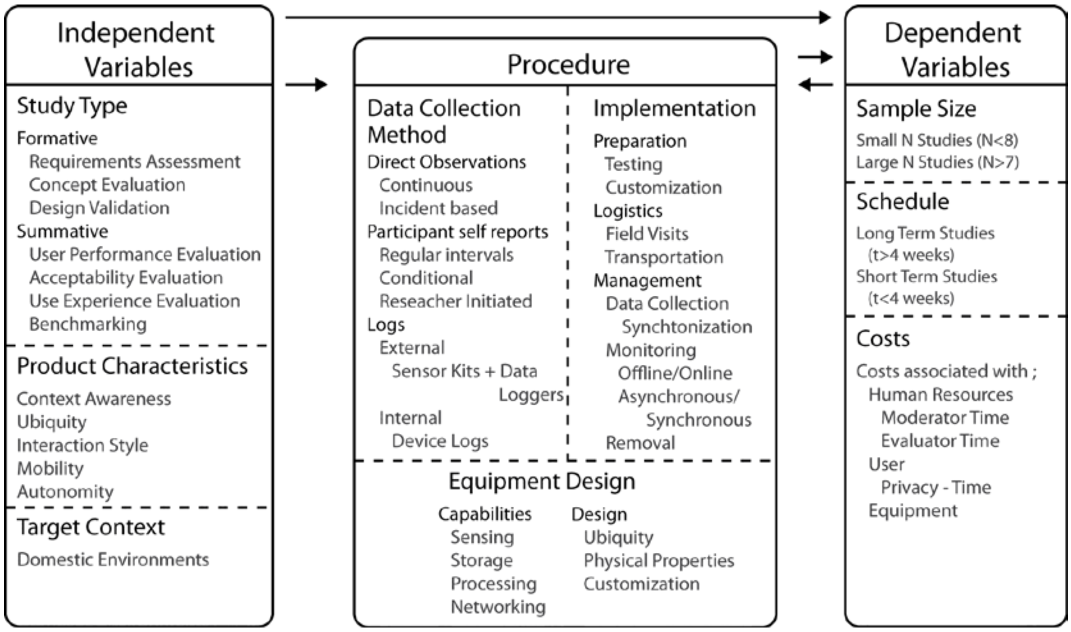


Figure 12 The links between independent variables, data collection procedure and dependent variables of domestic data collection method.

4.4.1. Sample Size

Being able to generalize study findings is an important aspect of research design and sample size is an identifier of generalizable results for quantitative studies. However, user research studies in real domestic environments are conducted with low number of participants and the findings are hardly generalizable to a population. Charlton and O'Brien (2002) reports that results coming from small samples can lead to erroneous conclusions from data. In order decide on a sufficient sample size for statistically significant results, information about the target population is required; which is generally missing for new product development studies (Rubin, et al., 2008). Rubin et al (2008) suggests that testing 10 to 12 participants *per condition* for usability studies is a safe approach to report findings. They also argue that testing 4 to 5 participants might reveal 80 percent of major usability problems but noted that increasing the sample size as much as possible increases the reliability of research study.

Although larger sample sizes (N>10) are sought for in context user studies (Rubin, et al., 2008), components of data collection, such as the need for complete observation of everyday life, logistics of test equipment and management of equipment in participants' houses, as well as researcher time hinders studies with larger samples.

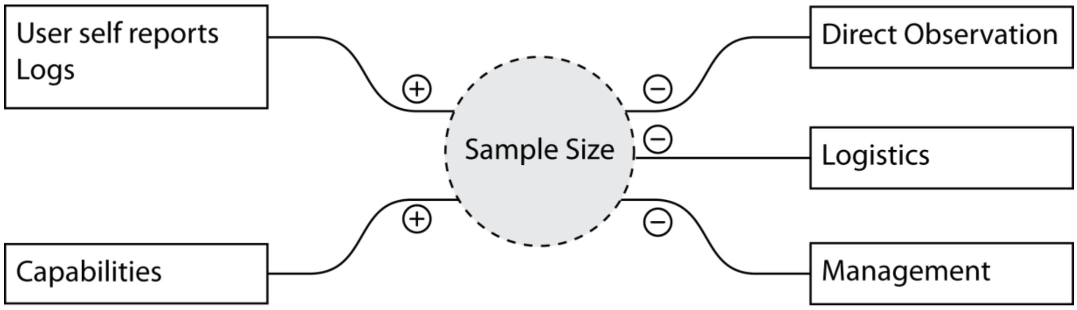


Figure 13 Implications of data collection procedure on sample size

There is a consensus on increasing the sample size for obtaining more reliable and generalizable results from user research studies; however it is not practical for ethnographic studies (Kalof, et al., 2008). Domestic data collection method suggests that utilizing data collection equipment that can work standalone and customized to match study and contextual requirements can give researchers the opportunity to conduct studies with larger samples (Figure 13). Once the data is digitally captured with device logs, sensor kits and self report tools, it is more convenient to analyze, share and present data.

4.4.2. Study Duration and Schedule

Ethnographic studies in social sciences have extended durations for user research studies. Although, ethnographic methods are good for observing social groups, it is impossible to live with participants in their own homes for months; hence, various methods are being utilized to replace the presence of ethnographers in participants' houses for prolonged durations.

Field visits, interviewing and self report tools are among the most popular ethnographic data collection methods that require shorter durations. Although these methods gather observational data from context, they took a snapshot of use and participants' subjective ratings of the product or activity. On the other hand, coupling of ethnography with digital data collection tools offers a continuous data collection for longer durations.

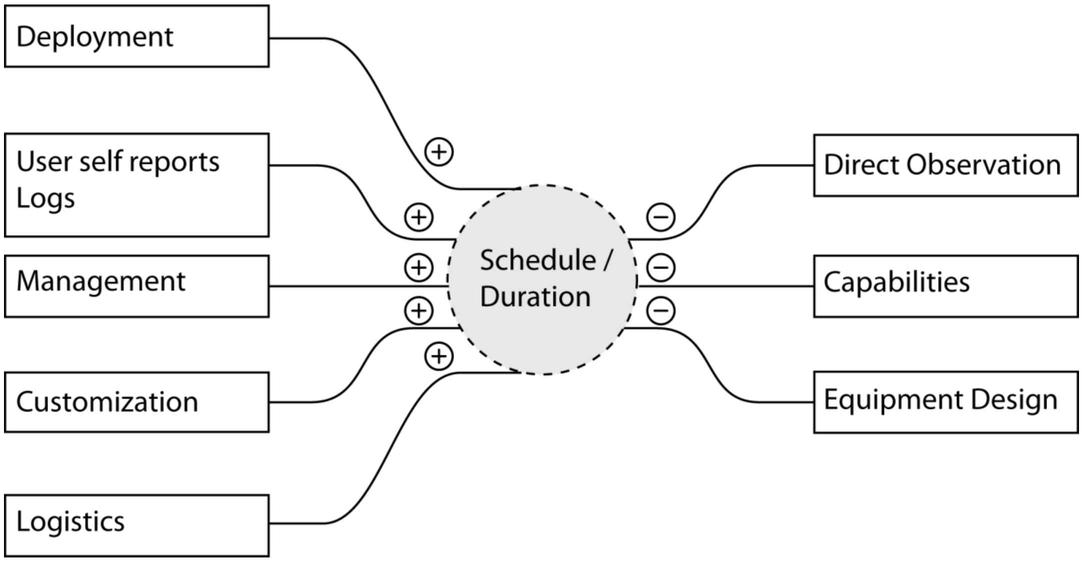


Figure 14 Implications of data collection procedure on schedule and duration

Although utilizing technological data collection equipment shortens study durations, logistics, customization, deployment and management of these equipment require extra time during the study (Figure 14). Moreover the schedule of planning, implementation, field visits and removal from the context are dependent on data collection equipment' physical characteristics and adaptability to the target context. Unexpected conditions such as problems with logistics, customization at context or maintenance during the study might extend study duration and alter the schedule of the study.

4.4.3. Costs

User research studies require resources such as researcher time, participant time, facility and equipment time. However, ethnographic data collection from real use environments requires an additional resource such as participants own environment. An in-context study has costs associated with;

- *Human resources,* in which ethnographers spend time in context and in laboratory for the coding and analysis of data,
- *Participants,* the study is mainly conducted in their homes, they provide space for data collection equipment. They dedicate their leisure time to user study; if necessary they report their thoughts, keep diaries or participate in interviews. Participants compromise their privacy by giving consent to be observed through their everyday life.

- *Equipment,* Data collection from contextual environments without the presence of human ethnographers relies heavily on technological tools which are usually custom designed, complicated and financially expensive to maintain. Besides their financial costs deploying and customizing them in different contextual environments require expert knowledge, which in turn costs human resources.

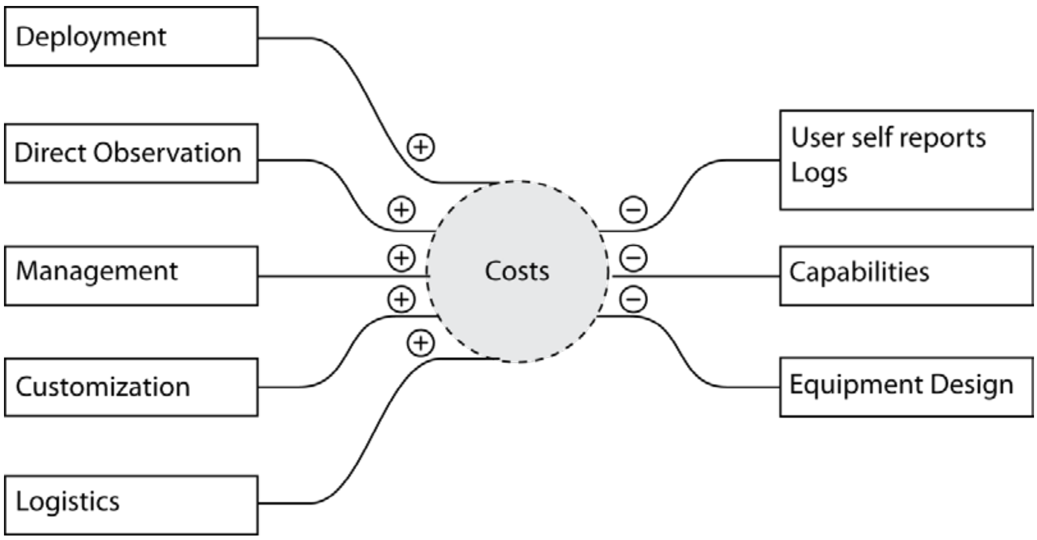


Figure 15 Implications of data collection procedure on costs

While data collection tools range from live-in laboratories to simple data loggers, both have costs associated with them. The former is a general purpose approach which can be utilized for continuously collecting data on everyday life of participants, for the expense of logistics, customization, extended testing, maintenance, management and participant privacy (Figure 15). The latter is a to the point approach which can be utilized for observing specific interactions for the expense of losing most of the contextual data.

4.5. Data Collection Procedure

The second phase of domestic data collection method deals with data collection procedure based on the variables of the study. The procedure has three major steps which are identification of data collection method, design and customization of data collection equipment and finally the implementation of the equipment (Figure 16).

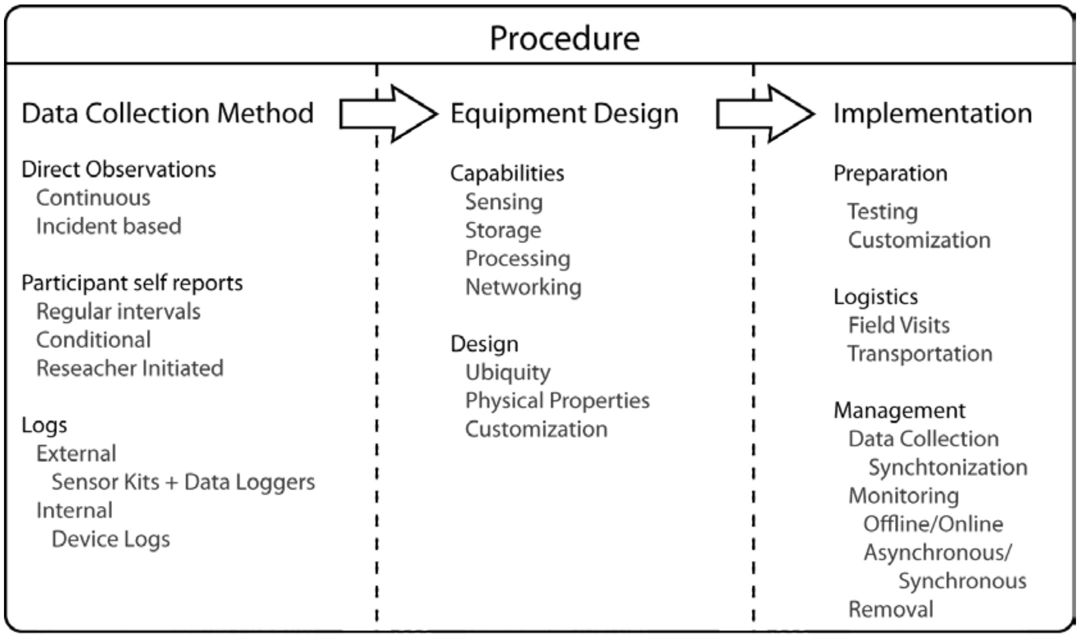


Figure 16 Overview of data collection procedure

4.5.1. Data Collection Method

In this study three major data sources are identified for domestic environments, which are, (1) the environment itself and the activities conducted within, (2) participant self reports and (3) automatically generated device logs. All three can be collected with technological instruments to some degree, however complete digital representation of context, user activities, preferences and interaction with the product increases the complexity of data collection tools; hence an optimization is required for the efficient utilization of financial, temporal, spatial and human resources.

Data related to the environment and the activities conducted within might be collected with direct observation. Direct observations can be achieved with the presence of human ethnographers for short durations or with audio/video recordings of the environments with longer durations. Complete observation of a domestic environment with audio/video recordings involves installation of multiple cameras and microphones per room and local high capacity digital data storage units.

Although audio visual recording provides a rich representation of use environment and activities carried within, the equipment that needs to be installed in the environment should not influence daily activities of participants.

In order to minimize risks of domestic data collection and collect subjective data, participants might be asked to respond self reporting tools, such as probes. A variety of probes have been utilized for in context user studies since they are first introduced by Gaver, Dunne, & Pacenti (1999). Self report tools can vary from simple pen and paper diaries to digital photographs and text messages to scheduled phone calls or video recordings from participants' eye (See 3.5.3.2). These tools can be utilized as supplementary data sources to triangulate automatically collected data.

For formative studies, self report tools can be utilized to collect subjective user data. Usually self reported data is analyzed for further inquiry in a session with the participant and evaluator, such as a contextual interview. Aims, goals and objectives of the participant, problems with use, expectations from the product, satisfaction from the interaction can be collected in order to understand participants' mental model and subjective ratings.

Self report tools by definition depend on participants to provide their responses to certain tools such as diaries, questionnaires, interviews etc. Giving responses to these data collection tools require reliance on participants' memory to recall certain events, feelings, preferences and experiences. Moreover, for repetitive routine activities it might be very difficult for the user to report every time the activity or interaction occurs. For these kinds of activities and for annotating direct observations utilizing device logs might be an effective alternative.

Smart products can detect motion, gestures, voice and contextual factors and utilize them as input or output interfaces, which might serve as a data source. Additionally logging interface events and synchronizing them with other data sources might deepen the data. Moreover, device logs might decrease analysis times by automatically marking critical events during usage.

Logs can be recorded by the product under study or with some external sensors and data loggers. Internal logs which are kept by the product itself provide data on interface events whereas external logs provide data on contextual factors and interaction with the product.

External data logging is similar to internal data logging in functionality as it requires sensors and memory to collect data. However, external logging can be utilized to digitize any kind of contextual events such as mobility of participants in the domestic environment, physical factors such as temperature, humidity, vibration, noise levels etc. External logging gives researchers the freedom to customize data collection and focus on certain tasks or products for longer durations.

Although, the financial cost of sensors, processors and memory are getting lower every day, expertise on the utilization of these tools for data collection is necessary. With the utilization of external and internal logging it might be possible to observe more subjects in shorter periods of time in a cost effective manner. Moreover, data logging offers simultaneous data collection from multiple sites. Conducting user studies simultaneously in multiple sites with traditional ethnographic methods would be financially expensive and prone to evaluator effect (Hertzum & Jacobsen, 2001) as different evaluators will be present in each site. On the contrary, standalone data collection equipment can be deployed simultaneously; therefore, increase number of subjects for a given time period in a cost effective manner and avoid the observer bias and evaluator effect.

4.5.2. Equipment Customization

Conducting user research studies in context for longer durations is a challenging task in terms of data collection equipment design and customization. Although target context is identified as domestic environments, the physical and social contextual factors are different for each study participant. Presence of kids, pets, elderly, room layout, qualities of surface area, furniture, position of windows, illumination make every house a unique data collection site. Data collection equipment that runs smoothly at controlled environment of laboratory might face social and physical contextual factors at the field. In order to address these factors data collection equipment needs to be customizable to adapt variations of contextual environments. Customization of data collection equipment is discussed under three major titles; capabilities, design and management.

4.5.2.1. Capabilities

Any data collection equipment to be utilized in contextual environments needs to have at least sensing, processing and storage capabilities. Collecting data requires utilization of sensors whereas storing it requires utilization of data loggers, such as hard disk drives, memory cards, memory chips or network storage. In addition to sensing and storage, a processor maintains the communication among these units and performs additional tasks.

In order to speed up data analysis, data collection equipment might process data as soon as it is collected and store pre-processed data for analysis (Meyer & Rakotonirainy, 2003). Processing data at sensor level can filter the data and might reduce data size prior to analysis. Audio/video data which generates the biggest share of data size can be annotated with device and sensor logs for shorter analysis durations (Ylirisku & Buur, 2007).

There are various types of sensors that can be utilized for triggering audio video annotation or recording contextual information. Temperature, humidity, acceleration, state change, motion, noise, vibration, location and light intensity are among the common sensor types. They collect data and send the values to a local storage device or they send the data on a local or wireless network. Communication among devices is critical as time and date information on each device have to be synchronized among all of them. For example, if the cameras are unsynchronized, participant might seem to appear at different rooms at the same time.

In summary, data collection equipment designed for domestic environments need to have;

- *Sensing;* equipment should be able to sense and digitally represent physical and social factors with sensors.
- *Storage;* Equipment should be able to store digital data and retrieve when needed. The data size might vary from a few kilobytes to a few terabytes.
- *Processing;* Equipment should have processors to control sensors and process data for storage. Processors might vary from simple PIC chips to high end PC processors.
- *Networking;* Equipment should have a local network for synchronizing various devices in context. Besides local network, an internet connection is necessary for reporting system status and receiving commands.
- *Power Management;* AC power is necessary for audio video and storage devices. Mobile, standalone devices such as small sensors and data loggers require battery power.

4.5.2.2. Design

Data collection equipment is a product to be utilized in domestic environments and need to be imperceptible to the user and the activities under observation, hence should be designed accordingly. Their design needs to satisfy all stakeholders, namely, researchers, technical operators and the study participants. During the course of their usage, data collection equipment need to be transferred, installed and then removed from many contexts and stored when they are not in use.

Their physical dimensions should be suitable for home usage and they should be light enough to permit carrying and installation. Additionally they need to protect sensitive high technology tools and they should give access to them when needed. Moreover they need to house and hold various sensors in particular positions (for example cameras and microphones).

People are generally are not fond of being observed and act unnatural if they are continuously reminded of being observed (Ylirisku & Buur, 2007), consequently data collection equipment has to be blended in participants' houses. Another reason for the ubiquity of data collection equipment is changing the context at minimum so as not to affect participants' daily activities. Moreover, heat and noise generation by data collection tool must be at insignificant levels for minimum burden to the house participants.

The physical conditions of every house are different; therefore data collection equipment might be customizable to various conditions. Equipment should be modular and might enable the variation of number of sensors installed in a house based on the room layout, number of objects and subjects in a house. Customizing the equipment and testing it in context might increase the precision of data and generate more reliable results. After the installation and customization, equipment might be left to collect data as a pilot test before actual data collection begins.

Customization of equipment to the research study, participants' preferences and target context is followed by the implementation of equipment for actual data collection in data collection procedure.

4.5.2.3. Implementation

Implementation of domestic data collection method covers;

- the preparation of equipment, researchers and the participants for the study,
- logistics of human resources and equipment and their allocation to participants,
- the management of data collection during the study.

Preparation

Besides the customization of data collection equipment, the participant and the research team might also need to familiarize themselves to the data collection procedure. Before distributing data collection equipment to the houses, participants might be invited to the laboratory or visited for debriefing about the study and they should familiarize themselves with the functionality and physical form of data collection equipment. For example, if data collection equipment is utilizing cellular network for internet connection and the reception at participant's house is low, then the site might not be suitable for data collection. If data collection equipment is self standing and its physical dimensions and components need to be distributed in the environment, an early field visit to the participants' houses might be necessary to observe the layout of furniture and rooms for installation.

Logistics

The scope of logistics in domestic data collection study is the effective transportation of human resources and equipment between research laboratory and participants' houses. Logistics activities are mainly a function of sample size and increases proportionally.

In order to plan logistics in an effective way, familiarization with the equipment and procedure might be necessary prior to field visits. Collecting information on the setup process, target context and architectural plan of the data collection site might have effects on the time spent in participants' houses. Based on the duration of field visits allocated for each participant, logistics might be planned in a cost effective manner for studies with large number of participants.

Management

Data collection equipment supposed to be left unattended at participants' house for the duration of study and expected to work standalone. During this duration equipment might need to be monitored regularly for possible errors and might need to be managed if necessary. Possible errors might be the displacement of sensors, freezing of data collection, drained batteries or failure of one or more sensors. In order to overcome these errors, system health can be checked in regular intervals and necessary actions should be taken to avoid data loss.

Besides equipment, data itself might need to be monitored for planning the next iteration of study. For example if a participant reaches to a certain level of expertise with a product, another set of tasks might be sent to that participant. Although it will not be practical to transfer video data, interaction and sensor logs or snapshots of use or critical incidents might be sent over the network to researchers.

Data must be synchronized among different data sources to compare real time events, such as user reported incidents with interface events and sensor readings. Unsynchronized data might mislead researchers on understanding the course of activities at context.

4.6. Deployment

Deployment of data collection equipment starts with the first visit at participants' houses and ends with removal of them. Deployment procedure can be divided into four major parts such as; customization of data collection procedure, logistics, monitoring and maintenance, where monitoring covers the actual recording of data on storage devices (Figure 17).

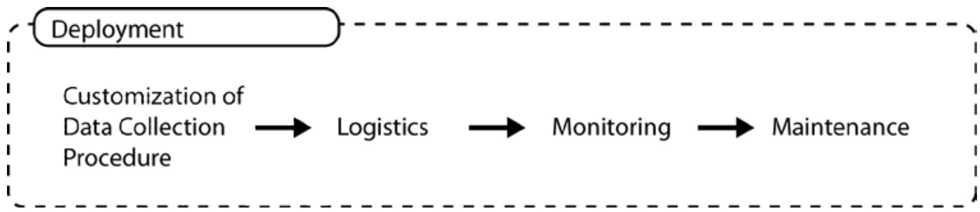


Figure 17 Deployment procedure

4.6.1. Customization of Data Collection Procedure

Data collection procedure might require different levels of customization. First of all the procedure needs to be customized to study type, product characteristics and target context, secondly it needs to be customized to sample size, study duration and budget constraints. Finally, after the main structure of the data collection procedure is set, the equipment and deployment plan might be customized to individual requirements of each data collection site. A standardized checklist for each site might help the customization of data collection procedure.

Observation and assessment of the site, customization and implementation of equipment and pilot testing need to be completed prior to actual data collection. Therefore, at least one house visit is necessary to the participant. Based on the procedure and data collection equipment, these tasks might be completed in multiple visits. However, keeping the number of field visits as low as possible might be essential for the cost effectiveness of user research study.

4.6.2. Logistics and Monitoring

After the customization and pilot testing of the equipment, actual data collection should start. After this point data collection equipment supposed to work standalone until the end of the data collection study. However, the collection procedure should be monitored for possible errors. If an error is identified it should be repaired preferably from remote locations.

Besides the data collection equipment, the data might need to be monitored for possible iterations to the data collection procedure. Possible critical incidents might be monitored synchronously and the study procedure might be updated accordingly.

At the end of data collection, one final visit is necessary to remove the equipment and the data from participants' houses. The data must be transferred to the lab and needs to be secured to protect participants' privacy.

4.6.3. Maintenance

After the data collection is completed and the equipment is transferred to the laboratory. Data collection equipment needs to be prepared for the next study. After the transportation of equipment to laboratory, they must be reset and prepared for the next data collection study. If required data collection equipment must be re-calibrated for the reliability of data collection.

CHAPTER 5

THE EMPIRICAL STUDY

Two case studies are conducted and the method presented in section 4.2 is revised based on the findings of case studies. The case studies aimed to cover domestic data collection method with respect to planning, procedure and deployment phases. Case studies are formulated to include diverse values of independent variables that are defined in the proposed method. Study type, product characteristics and target use contexts were varied in each case study. The first case study was a formative evaluation of a ubiquitous product in a single occupant house whereas the second case study was a summative evaluation of a conventional product in various domestic environments.

The first case study aimed to evaluate utilization of standalone data collection equipment, and device logs for the observation of a ubiquitous smart product. Complete everyday life of a single participant is observed throughout the study. This study utilizes high-end data collection equipment that is able to collect multi modal data from complete domestic environment, which is designed to transform study participants' own houses into a live-in laboratory.

The second case study aimed to evaluate utilization of device logs and external data collection equipment for the observation of a specific functionality of a consumer product in larger number of samples for longer study durations. This study employs simple to-the-point data collection tools together with device logs for digitally representing the user interaction with the product.

Both of the case studies are conducted in participants' own environments; however, they differ in terms of user research study type, sample size, data collection equipment and product characteristics.

5.1. Case Study 1: The Design and Implementation of a Standalone Sensor Kit

In this case study a novel portable sensor based data collection kit, *BoxLab* is utilized to evaluate a smart product designed for in context foreign language learning, *Foreign Phrase Learning Tool (FPLT).*

5.1.1. Study Setup

This case study has been formulated to observe the role of digital ethnography tools, self reporting and device logs in the naturalistic observation of a ubiquitous smart product. In addition to this, data collection capabilities of the tool; BoxLab, which is designed to instrument participants' own houses with technological data collection, is evaluated during the course of this study.

First, the requirements assessment and fit criterion (Robertson & Robertson, 2006) have been set for both FPLT and BoxLab, then, based on these requirements and product characteristics, study participant has been recruited. FPLT is an always-on ambient and distributed tool, once set up it does not require any user intervention. It takes daily interactions with domestic objects as input and responds accordingly. With these general characteristics and the aim to observe complete interaction, it was decided to capture complete everyday life with audio video recordings.

During the course of the study user observation data has been automatically collected with BoxLab, which has been designed prior to this study. BoxLab is aimed to merge all the tools and functionalities of a live-in laboratory in a portable scale; thus, converts any domestic environment into a live-in laboratory. The design and capabilities of BoxLab will be presented in the following sections.

The huge amount of data (almost 600 Gigabytes) has been analyzed with *Handlense*, a software tool developed at MIT House_n Research Group for recording and analyzing data collected from PlaceLab, a live-in laboratory (Stephen S Intille, et al., 2005). The tool synchronizes the sensor data and audio/video streams and plays them on a visual sensor map. As this tool has been designed for a local live-in laboratory, this study has been also served as an evaluation environment for the design of next version of Handlense for BoxLab.

5.1.2. Study Procedure

It was aimed to recruit one participant for 7 days including two days of setup and removal of data collection tool. However due to logistical reasons participant has been recruited for 6 days. During this period 3 visits were planned to participant's house. First visit would be for observing the data collection site; getting the floor plan and working on possible sensor locations. Second one would be for deployment and the third and the last one was for removal. However, during the study an extra visit was paid, because of some complaints from the participant.

In the following subsections recruiting, the product under study, user observation requirements, data collection equipment and process will be presented in more detail.

5.1.3. Research Team

Case study was designed and conducted at MIT House_n research group. Two senior software developers and a senior industrial designer (current researcher) were involved in the research team. One of the software developers was responsible for the design and development of foreign phrase learning tool, whereas the other was responsible for the development of various software tools for BoxLab. Current researcher was responsible for the transformation of PlaceLab which is a live-in laboratory to BoxLab, a portable data collection kit.

Current researcher designed the BoxLAB system layout and the physical enclosures based on the requirements identified by the research team. Moreover, assembly of hardware components of BoxLAB and their integration with software tools are also current researcher's responsibilities. Together with the design team current researcher designed the implementation process of BoxLAB and FPLT. During data collection process house visits are carried out with the current researcher and one of the software developers.

After the study, data analysis tasks are carried out by the current researcher.

5.1.4. Recruiting and the Participant

Recruiting criteria have been defined in relation to the characteristics of foreign phrase learning tool (FPLT) and BoxLab based on the following;

- Study participant have to live alone (no pets as well)
- Study environment (house) shouldn't be multistory and larger than 200 m^2.

- Study participant should be a part time worker or retired.
- Participant should leave in the vicinity of Greater Boston (MA, USA) area.

These criteria originated from the following practical reasons; both the FPLT and BoxLab are prototypes, hence, single user interaction is preferred for evaluation, wireless network coverage is needed therefore the house should be as large as the coverage, participant should spent most of his/her time at home for an efficient implementation of equipment and because of logistics participant should live in a close distance to the laboratory.

An ad about the study was issued in a local newspaper and asked interested parties to respond via an online screening survey. Based on the screening survey 18 respondents were identified as participant candidates and they were asked to complete a recruiting survey. Out of 18 respondents a 73 year old retired male, who is living alone has been selected as study subject. Then, he was invited to the laboratory briefed about the study, FPLT and data collection tools. After this briefing he expressed his willingness to participate in the study and agreed to sign the informed consent form.

5.1.5. The Product: Foreign Phrase Learning Tool

Foreign phrase learning tool (FPLT) is being developed at MIT House_n research group based on Language Learning Tool (Stephen S. Intille, Lee, & Pinhanez, 2003). Language learning tool displays random words on almost any surface in a living room and was designed to help learning the vocabulary of a foreign language in the course of everyday life. Although it was created to run continuously in the background it was always ignorable. Contrary to its predecessor's random phrase display in text format, Foreign Phrase Learning Tool (FPLT) triggers based on the interaction with specific objects and plays phrases associated with these objects and utilizes speech based interaction.

The basic function of FPLT is to teach foreign phrases to house residents during the course of the day while they are conducting everyday activities. After the tool detects interaction with a physical object it plays the associated phrases, first in users' native language than in a desired foreign language. The tool always runs in the background and waits for user interaction with an everyday object and plays voice clips accordingly.

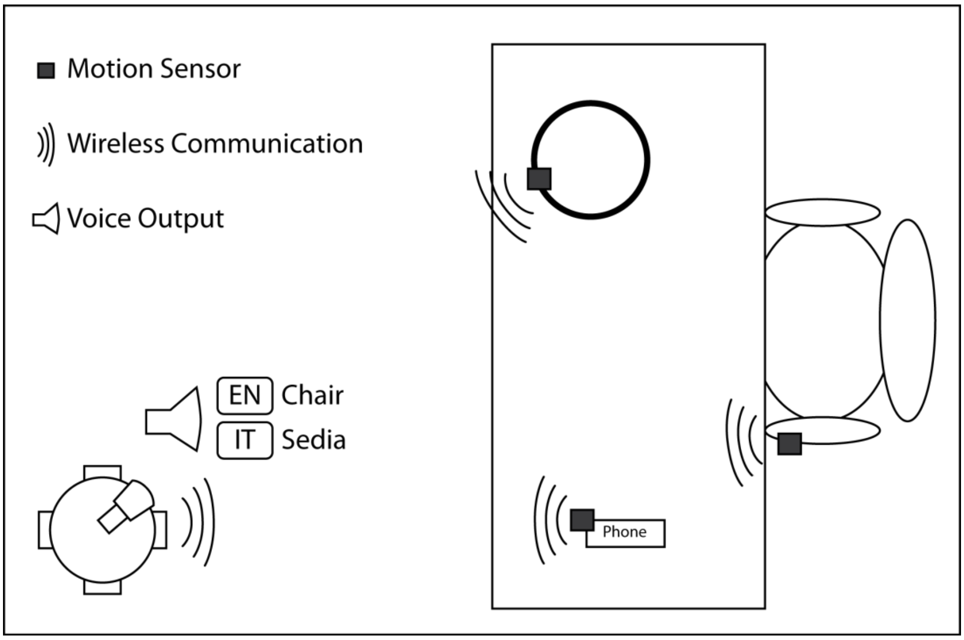


Figure 18 Foreign Phrase Learning Tool Schematics

FPLT ubiquitously monitors object motion and tries to infer interaction based on this information. In order to detect interaction with physical objects the tool utilizes small wireless motion sensors that are attached to objects (Figure 18). The sensors report the magnitude and frequency of motion and send this information to the computers inside the kiosks. Then the computer analyzes this information, matches the sensor ID to the specific voice clip and plays the voice clips from kiosk located in the desired room.

5.1.6. Aims and Objectives of FPLT Study

FPLT is an early prototype and still under development, hence the study is a formative study that aims to collect user expectations, anticipations and assumptions generated by interactions with a ubiquitous smart object.

There are two main challenges to overcome during the development and installation process for FPLT. The first challenge is to deliver voice clips without disturbing users' daily activities and the second one is ubiquitously attaching sensors to users' personal objects and placing kiosks that play the phrases in the environment.

In line with these challenges the design team set up a series of requirements and success criteria for FPLT. The requirements have been listed *under functional, data, environmental, user and usability* titles (Preece, et al., 2001)

Functional requirements;

- The tool will play phrases associated with objects
    - The tool will detect motion in a reliable way (it should omit small vibrations and will not miss actual interaction)
    - Sensors will report object use to the computers (network should work smoothly)
    - Computers will play the associated phrases based on signals received from sensors
    - The phrases must be clear and easy to hear in the room and nearby
- The tool will be muted and un-muted depending on user's preference
    - The tool will be always on
    - Depending on user's preference and social context the tool will enable muting and un-muting
    - Un-muting might be automatic and time dependent.
- The tool will allow users to add, remove and change sensor locations, associations and phrase lists.
    - The tool will allow modifying sensor locations
    - The interface will enable user to modify sensor-phrase associations

Data requirements;

- The tool does not need any external data. However, it detects interaction with objects and creates its own dataset.
- The tool needs data on ambient vibration characteristics of physical environment. Physical context should be observed before installing the tool. The vibration levels and vibrations caused by large machinery must be recorded, thus sensors must be calibrated based on this data.

Environmental requirements;

- Sensors need to be attached to various objects with different sizes, shapes and surface qualities in a limited time.
    - Sensors must be attached and removed without giving any damage to objects and should not leave any residue or parts on the object.
    - Attaching and removing sensors should be easy and can be performed by untrained personnel and users.
    - Sensor IDs must be visible and easy to read

- Kiosks will be placed in each room
    - Kiosk will aesthetically fit in residential environment.
    - Kiosks will create tolerable heat and noise
    - Kiosks placement should not interfere with user's daily life.
    - Kiosks will be portable and easy to carry. (carrying kiosk should not damage physical environment)

User Requirements;

The tool blends into the physical environment and will be used by interacting objects. Hence, target user population is almost anyone (except hearing-impaired people for obvious reasons). However, there might be problems with pets. The sensors might not be suitable for pet-toys or objects for pets.

Usability Requirements;

- Initial set up will be easy
    - Initial set up routine will be as follows
        - pick a sensor,
        - identify it to the computer,
        - attach to a physical object ,
        - associate with phrase(s)
        - repeat it for the next sensor,
    - The user interface for conducting initial set up must be clear and understandable.
    - Initial setup must be error free as it might cause frustrations during use (e.g. faulty sensor-object-phrase associations)
- Using FPLT will create a pleasant user experience
    - Users will interact with the tool while interacting with physical objects.
    - Users will be able to mute the tool according to the social and physical context (presence of guests, listening to music etc.)
    - The latency between objects use and phrase playing will be minimum.
    - Phrases should be played with a clear and audible voice; the sound level will be adjustable.
    - The tool will enable users to learn different words after initial set up
    - Users will be able to associate sensors with new objects and phrases.

- FPLT will filter out frequently used objects and phrases in order not to repeat certain phrases.

Requirements and Fit Criterion

In order to test the requirements against certain criteria Robertson and Robertson's (2006) requirements and fit criterion template has been utilized. According to this template each requirement is coupled with a *Fit Criterion,* which describes the successful realization state of requirement. The requirements for FPLT and their fit criteria are presented in Table 3.

Table 3 Requirements and Fit Criteria for FPLT

Requirement	Fit Criterion
Functional Requirements	
The tool will play phrases associated with objects	Each and every sensor firing shall trigger computer to play phrases. False positives and true negatives shall be less than % 10 of object use.
The tool will be muted and un-muted depending on user's preference	The tool shall enable user to mute and un-mute the application. Un-muting shall be automatic after certain period of time or at certain times of the day.
The tool will allow users to add, remove and change sensor locations, associations and phrase lists.	The user interface shall enable users to add, remove and change sensor locations, associations and phrase lists. The tool shall enable user to change native and desired languages.
Data Requirements	
The tool needs data on ambient vibration characteristics of physical environment.	The tool shall collect ambient vibration data and automatically calibrate itself.
Environmental Requirements	
Sensors need to be attached to various objects with different sizes, shapes and surface qualities in a limited time.	Sensors shall be attached in a robust manner. Sensors shall not fall off or permanently stick to objects.
Kiosks will be placed in each room	Kiosks shall fit physically and aesthetically into users' environment. They shall not produce excess heat, noise or physical damage to physical environment during deployment and removal. Kiosks shall not distract users' daily routine.
User Requirements	
No requirements for the user	
Usability Requirements	
• Initial set up will be easy	Users shall be able to setup the tool with minimum error. For a kit of 30 sensors; Tool setup should take less than an hour, shall be less than 3 wrong sensor associations. The tool shall provide feedback and error recovery at each step of installation.
• Using FPLT will create a pleasant user experience	The tool shall engage user to learn phrases at his/her own pace. In addition to daily activities user shall deliberately move things or repeat after computer to learn phrases. Kiosks and sensors shall not obscure or distract user's everyday activities.

5.1.7. Contextual Environment

The study has been conducted in participant's own environment, which was an apartment at 12th floor of a high rise building. The apartment had 3 rooms, an open kitchen and 2 bathrooms (see Figure 24). There were one study room, one bedroom and a living room. The apartment had hardwood floors with classical style furniture. Windows were big and permits direct sunlight to the rooms. The building was near the ocean and there is ambient water sound. In addition to this constant sound, there was maintenance in the building during the study. Noise and vibrations were coming up from construction equipment.

Participant was living alone with no pets. However, he mentioned that he usually has visitors in the evening, but they don't stay overnight. And a cleaning lady comes once in a week.

The contextual environment was challenging for object use sensors as they were sensitive to ambient vibrations. Also the ambient noise in the apartment had effects on sound recording quality. In addition to these, visitors created privacy problems, because of the always on audio video recording. In order to overcome visitor privacy issue, participant was asked to inform visitors and he was briefed to pause data collection anytime he wanted.

5.1.8. Data Collection Equipment

During the course of the study BoxLab have been utilized for data collection. Web based surveys have been utilized for participant screening and recruiting purposes. BoxLab passively records multi-modal contextual data, including complete object use, audio, and visual record. The presence of researchers and participant self-reports are not utilized to avoid interference with participant's daily activities. The system uses a set of lamp-like kiosks, containing the necessary hardware for data collection and processing and storage. One kiosk is placed in each room and each kiosk is responsible for the audio video data collection in that particular room. All kiosks are monitored by a central kiosk that provides the wireless connection and communication with the laboratory. The system expected to collect data continuously until the end of the study; however, the participant has the complete control over data collection and able to pause or end data collection at his own will.

Sensing capabilities of BoxLab is based on MITes - *wireless kit of sensors* (Tapia, et al., 2006) which have different types of sensors to collect movement, object use and environmental conditions such as light, temperature and humidity. The sensors work wirelessly and transmit information to a central receiver located in the environment. The audio/video recording capabilities and annotation software is based on the PlaceLab (Stephen S Intille, et al., 2005) which is a live-in laboratory.

Design Considerations and Requirements for Data Collection Equipment

BoxLab consists of sensing, storing and processing equipment. It is a portable and modular tool with two different sizes of enclosures. The main floor lamp-like enclosure houses processing and storage equipment, whereas the smaller desk lamp-like enclosure houses microphone, camera and a wireless A/V transmitter. Although some of the sensing devices are housed by the main enclosure majority of them are distributed all around the house. The main design considerations and requirements for BoxLab are as follows;

- BoxLab and its sensing devices aim to minimally invade study participants' living environment
- BoxLab needs to be portable for easy transportation and storage, however it needs to be stable and self standing once set up.
- The main enclosure and distributed sensing devices needs to blend into the home environment and domestic objects.
- The heat and noise generated by the equipment should be as low as possible.
- BoxLab should be built from off the shelf equipment wherever possible for easy replicability
- Assembling and duplicating BoxLab should be as simple as possible to allow other researchers to create duplicates of the equipment

Based on these requirements a number of design alternatives (Figure 19) have been built and evaluated according to the design criteria by the current researcher. Among these alternatives a plywood enclosure with a lamp on it was selected for development.

Figure 19 BoxLab early alternatives

The final design of the enclosures (Figure 20) are made with plywood panels cut to press fit with each other. The dimensions of the enclosure are shaped by processing, storage and power management equipment.

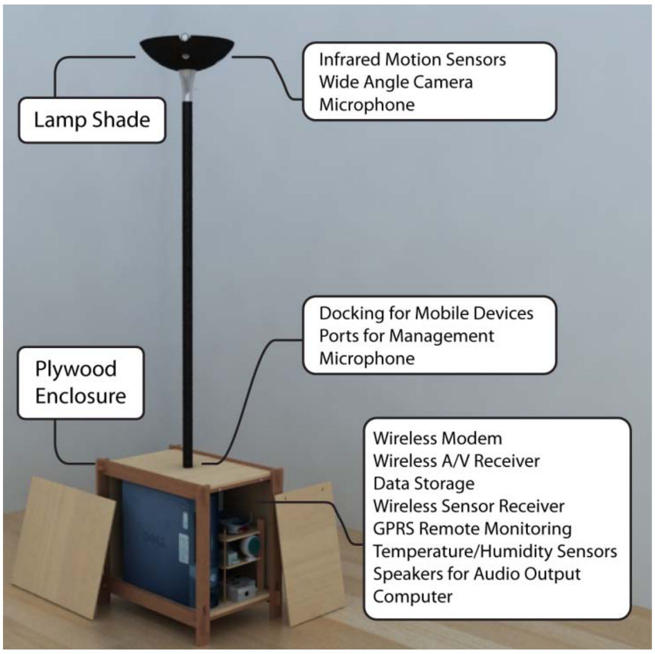


Figure 20 BoxLab design and layout

BoxLab system is composed of three different enclosures and distributed sensors (Figure 20). These three units are;

- **Central Unit,** Communicates with the researchers and other units, provides wireless network in addition to the sensing, processing and storage tasks. There is one central unit for each house.

- **Room unit,** Senses, processes and stores data, there is one unit for each room. Central and room units look identical, only the components inside the enclosure differs.

- **Satellite unit,** is used for focusing on certain tasks. Houses one camera, one microphone, A/V transmitter and their power adapters.

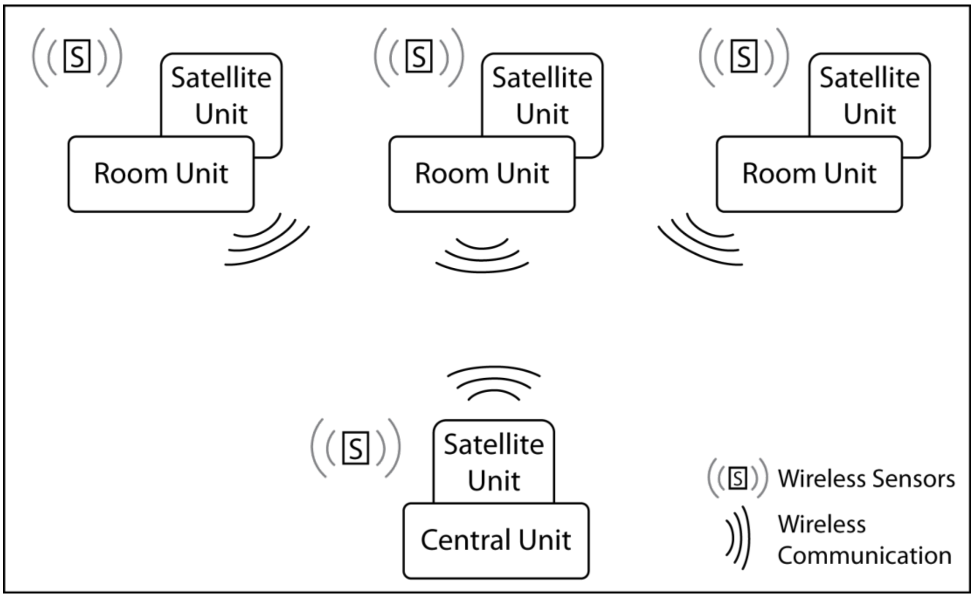


Figure 21 BoxLab System Layout

Components

BoxLab is a standalone data collection kit and has data collection, processing and storage capabilities. In addition to these primary functions it needs to monitor its state, communicate with laboratory and do maintenance tasks such as self reset. A sample system with minimum components is composed of one central unit, one satellite unit and wireless sensors.

To achieve reproduction and affordability, BoxLab is built from off the shelf components. A regular PC handles the processing and communication with data collection units, an external hard disk drive handles data storage, a wireless router creates a network for communication between data collection units, sensor receiver collects sensor activation data, speakers provide sound output and a gang of devices provide remote communication and power management (Figure 22). Cell remote control device provides internet access for the unit to communicate with the laboratory for monitoring purposes; internet power control transmits commands to controlled power strip and enables researchers to restart BoxLab from a remote location.

Figure 22 BoxLab Kiosk Components

A BoxLab with minimum configuration is presented in Figure 23. The central unit is demonstrated in Figure 23-A, satellite unit is demonstrated in Figure 23-B and wireless sensor is demonstrated in Figure 23-C. Central and satellite units are designed as lamp shades to fit into domestic environments. Wireless sensors have an off the shelf plastic case (Figure 23-C) which is small enough to be attached to almost any object in the house with a small amount of reusable adhesive putty.

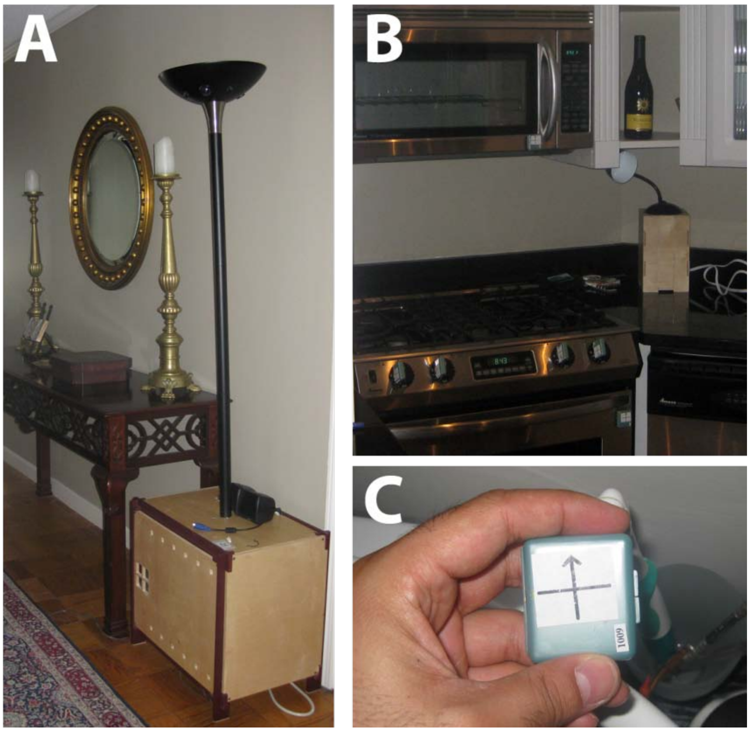


Figure 23 BoxLab components

5.1.9. Data Collection and Analysis

Direct observations and automatically generated device logs were utilized for data collection. Although it was not intended to utilize self report tools, participant has phoned researchers to report situations that he thinks critical during the study. However, these communications were related to the user experience with the FPLT. Direct observations were conducted with automatically annotated audio video recordings and device logs were utilized to represent functionality of foreign phrase learning tool.

BoxLab was programmed to collect data continuously during the course of the study and data collection was fully automatic. BoxLab enclosures were transferred to participant's apartment at first visit; however study couldn't be started during that visit. Subject's home was examined and a floor plan was drawn for mapping the sensors to the environment. Sensors and enclosures were deployed during the second day of the study. Three researchers spent 2 hours for deploying the system. Simultaneously with sensor deployment, sensor locations were documented for further reference.

One central unit, three room units and one satellite unit has been deployed for data collection. In addition to these units, there were 96 object use, 16 motion detection, 3 temperature, 2 humidity sensors with 4 wide angle cameras and 5 microphones at participant's own house. The layout of sensor and BoxLab Kiosk locations on participant's floor plan is presented in Figure 24.

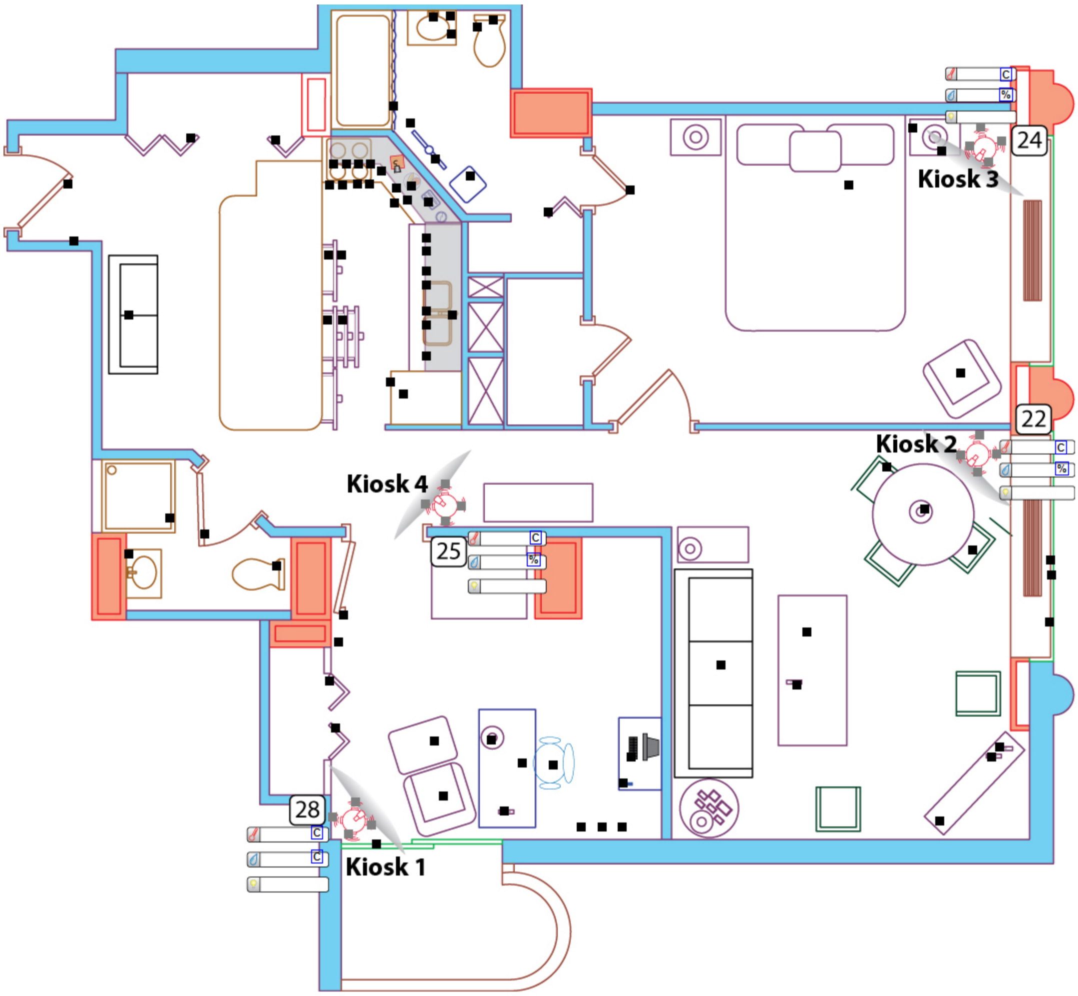


Figure 24 Participant's floor plan with sensor locations

Once BoxLab was up and running, researchers left participant's house. Although, BoxLab was connected to the laboratory via a cellular GPRS data line the data has been stored locally due to privacy reasons. Subject was free to delete all or part of the data before handing it in to the researchers at the end of the study. After initialization of data collection it was planned to visit participant at the end of the study; however, participant complained about the low volume and hardly understandable accent of Italian phrases and wanted the language or the Italian voice to be replaced; thus another visit was paid to participant's house to fulfill these requests.

After the end of the study data has been taken from the site. Participant did not want any part of the data to be deleted. 600 Gigabytes of video data has been reviewed with *Handlense,* a software tool specifically designed for recording and annotating data from *PlaceLab,* a live-in laboratory.

During the analysis, video data served as the ground truth for the evaluation of FPLT and performance assessment of BoxLab. Audio/video data has been reviewed and subject's actions have been annotated and coded thoroughly. The annotation and the output of sensor data from FPLT and BoxLab have been compared on a single timeline. Subject's daily life from the video data and from the sensors has been juxtaposed to see the similarities and differences. The resulting data has been analyzed for;

- Number of true positives (video and sensors tell the same thing)
- Number of true negatives (some detectable activity is going on but sensors miss it)
- Number of false positives (nothing is happening but sensors are firing for object motion)
- Number of situations in which video coverage is not enough.
- Number of explicit interactions with FPLT

Furthermore, activities are coded and analyzed for repetition and patterns to observe routine daily life of the participant.

5.2. Findings of Case Study 1

The results of the case study are presented in terms of data collection method, equipment design, implementation and deployment which are identified as the study procedure of domestic data collection method.

5.2.1. Findings Related to Data Collection Method

Direct observations with audio video recordings and automatically generated sensor logs are selected as data collection method. This combination of data modalities are assumed to give an overall observation of the everyday activities and interaction with the FPLT. However, because of the ambient interaction characteristics of FPLT it was challenging to observe participant interaction with the product. Participant did not interact with FPLT directly, FPLT interaction was ambient with interactions with the objects in the environment and the product is ubiquitous, therefore, the only way to evaluate participant's attention for these characteristics might be utilizing self report tools.

FPLT provides sound output during everyday activities, and data collection methods are able collect information on participant's actions and FPLT's corresponding reactions; nevertheless data collection methods failed to observe whether the participant is paying attention to the FPLT or not. In some cases, participant pokes objects, repeats phrases after the FPLT or waits besides the kiosk to hear the pronunciation of phrases. Other than that, data collection modalities failed to capture user attention to the FPLT.

5.2.2. Findings Related to Equipment Design

BoxLab design and configuration is customized according to the aims and objectives of the study and the data collection methods applied during the study. Foreign phrase learning tool requires detection of object movements in the environment to function properly; and it provides voice output after the detection of movement. Therefore detecting object movements and sound is critical for the BoxLab design for this particular study.

Detecting object movements and sound heavily relies on wireless sensors and microphones, hence audio / video recording capabilities of BoxLab served as a ground truth for the triangulation and validation of data sources. Besides FPLT, also the design and capabilities of BoxLab is evaluated, hence sensor activations are compared against video data.

During the analysis, if the sensors fire because of participant's interaction with an object then this detection is coded as a *true positive (TP)*. If the subject was interacting with an object, but the sensors fail to detect that interaction then it is coded as a *true negative (TN).* If the subject was not interacting with an object at all, but the sensors were fired because of some external factor then this firing was marked as a *false positive (FP).* And in some cases the video was not enough to infer activity, due to low frame rate or blurriness of the image or another object in front of the subject, these cases are coded as *Not Visible on Video (NVoV)*. In this analysis 96 object use sensors were analyzed, 16 motion sensors were evaluated separately using the same coding scheme.

Figure 25 shows the daily sensor activations and video data comparison. In the 6th day of the study data collection was conducted for 10 hours, consequently it is removed from the evaluation. It can be inferred from the data that sensors were effective in detecting object use in approximately half of the activities in average. However, in roughly 32 percent of the activities, they missed detecting the interactions. This might be due to technical problems such as poor or loss of network connection, as well as installation problems such as loose attachment of sensors to the objects.

In average fourteen percent of the sensor activations were labeled as false positives. This was due to the oversensitivity of sensors or the functioning of vibrating objects such as trash dispenser, washing machine, microwave oven or orange juicer, which was used in daily basis. In some cases particular sensors were fired even if the subject is not at home. This might be due to vibrations in the building, such as the movements of elevator or the passing by of a heavy vehicle from nearby streets. Moreover, one possible reason for the large number of false positives might be the construction and maintenance operations in the building hence heavy machinery was being used.

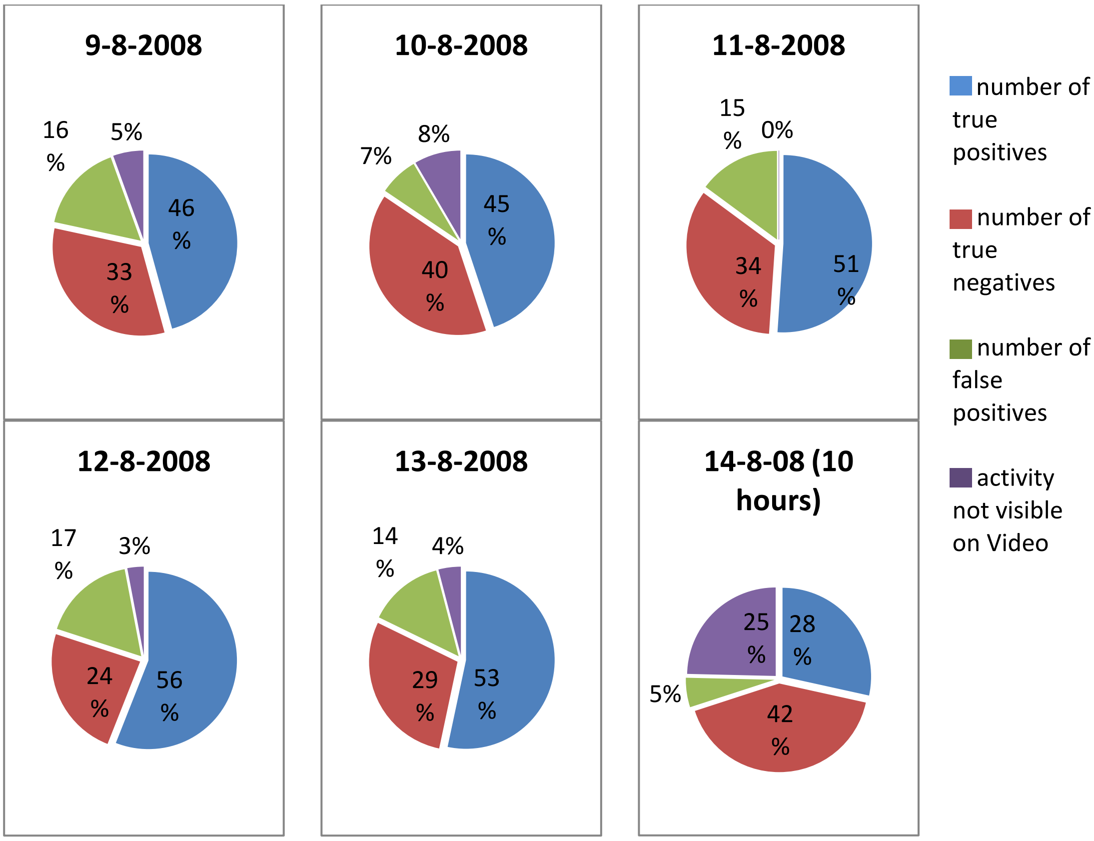


Figure 25 Daily comparison of video annotations and sensor data (M-tp:detection of motion, M-tn: fail to detect motion)

In average four percent of activities were not detected with video because of technical problems, such as; low frame rate or contextual problems; such as high brightness, low light or blocking objects in front of camera. For example living room kiosk was placed besides a table and a floor light; during the installation, camera had a good view of the room, however participant moves the floor light besides the table and in front of the camera while having dinner on the table. As a result of this, camera dims automatically to adjust the image quality and the subject became undetectable on video image because of the high brightness coming from the light.

The motion sensors recordings and subject's movements in the house have also been compared using the common timeline. However, this comparison is based on "detection of motion" (m-TP) or "fail to detect motion" (m-TN). Figure 26 demonstrates that motion sensors performed very poor on detecting motion in a reliable way. They missed almost 90 percent of all movements in the house. Their low performance might be due to errors in their sensitivity threshold or placement in the BoxLab design.

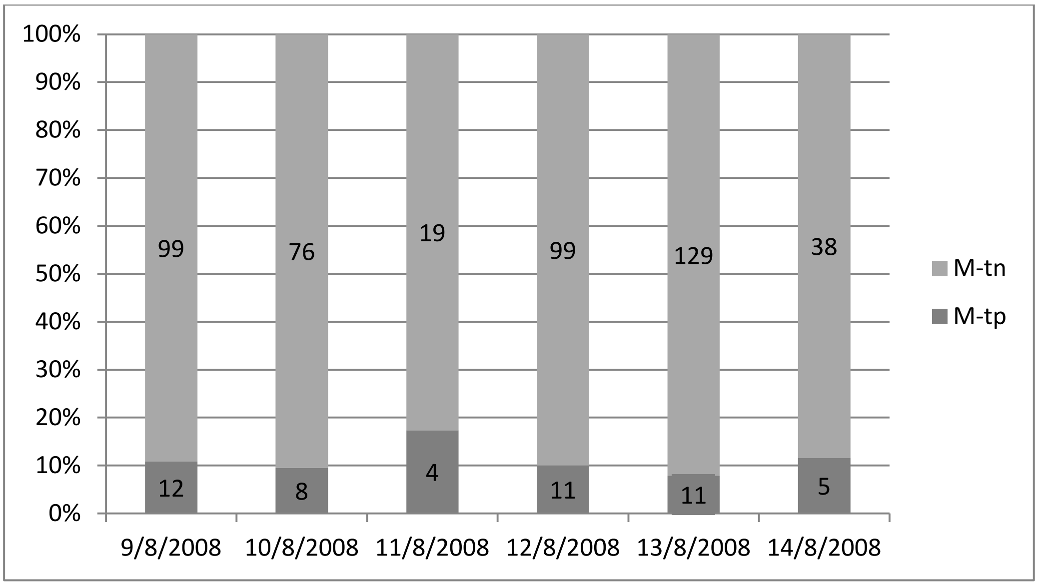


Figure 26 Comparison of motion sensors and video data

FPLT is an always on passive device, thus it is challenging to identify interaction with the tool. As a result, it was impossible to infer, whether the subject is listening the phrases or just ignoring them with the current design of the BoxLab. However, there were times in which the subject pokes objects, actively listens, goes and waits besides the kiosk or repeats after the kiosk. These activities are coded as direct interactions with the kiosk and annotated during the evaluation.

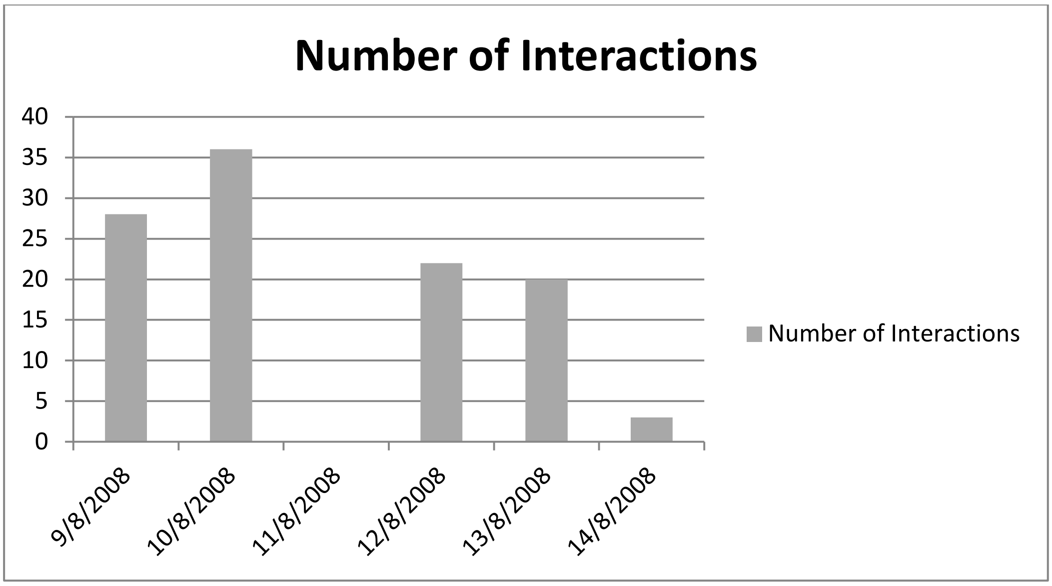


Figure 27 Number of Interactions with FPLT

Figure 27 demonstrates the number of interactions in daily basis. According to the figure on 11/8 interactions are zero because the participant unplugged BoxLab. And on 14/8 interactions are very low because it is the last day of the study; hence data collection is stopped at noon.

The graph shows decreasing number of interactions, which might be due to FPLT's novelty and decrease of this novelty by time (Law, et al., 2007). Another explanation to this, might be the ubiquity of the tool and interaction by time. Identifying the reason for this decrease is not possible with either sensors or the audio/video recordings. Although, direct observation of the environment provide data on activities, self report tools are necessary to understand participant's internal representation of interaction.

After his first day with the tool the participant have complained about the accent and pronunciation of Italian phrases, he also added that the sound from the kiosks were too low and hardly understandable. During the second day of the study researchers visited the participant and updated the Italian phrases and put speakers outside the kiosks and increased the volume levels. This improvement in interaction might also be the reason for the low number of detected interactions with FPLT as interaction might became undetectable and ubiquitous after the update to the system.

During the field visits participant expressed his interest in using the tool. And he also mentioned that he is comfortable with study tools and methodology. During the briefing at the laboratory, the subject expressed that to be recorded all day long, wouldn't be a problem for him however during analysis it was observed that he shut down the system for specific durations. Moreover, from the video and sensor data it was observed that subject has preferred to shut down bedroom kiosk before going to bed. During the removal of the equipment subject made clear that he shut down bedroom kiosk just before going to bed because of the noise coming from it. However, it was observed that he shut down kiosk before preparations for going to bed, and he started the kiosk after completing his morning routine. Although, he expressed his comfort with audio/video recording it was observed that he physically blocked recordings by unplugging the devices.

The loud noise was an issue because of the desktop PC computers and relatively small enclosures. The enclosures have limited air ventilation and computer fans run faster to cool down CPU, hence cause uncomfortable conditions. Although identical hardware was used among every data collection kiosk in the environment, participant only complained about the bedroom kiosk. Customizing bedroom kiosk with extra silent cooling system or utilizing extra padding for sound insulation might be a solution for data collection equipment's adaptation to contextual environment.

Participant's comments about the ubiquity of the data collection tools; kiosk enclosures and wireless sensors are promising. Participant reported that his daily activities, routines and interactions with everyday objects did not influenced by the data collection equipment.

5.2.3. Findings Related to Implementation and Deployment

BoxLab is designed to work standalone in participants' own environments; therefore it has to work robustly during the study. To ensure seamless operation, reliability testing and pilot data collection studies are conducted at the laboratory prior to implementation. BoxLab houses multiple systems for data collection, power management, networking, and storage and all of these systems need to be tested individually and synchronously for possible failures in operation. For example, sensor data transmitters and wireless network router worked perfectly in individual tests, however when the system put together it was found that wireless router network frequencies jam sensor network frequencies and causes missed sensor reports.

Data collection equipment requires power and it is supplied by wall outlets; however wireless sensors need batteries for operation. All batteries must be tested prior to deployment as battery life defines standalone data collection duration.

Data collection equipment must be set to start automatically as soon as it is plugged in to power outlet. Automatic power management and restart on demand functionalities must be tested thoroughly, cell phone coverage and modem link need to be tested to enable remote monitoring and management. To achieve power management a controllable power strip, internet power control and cell remote control devices are utilized in combination. Wiring and programming of these devices are the key tasks for remote management and any failure in this setup will likely result in complete loss of data.

Besides standalone operation functionalities audio visual capabilities are also need to be tested thoroughly prior to implementation. Audio/video capture capability of the system might work properly at the controlled environment of laboratory; however contextual factors such as low/bright lights and loud/noisy environment characteristic had effects on the quality of audio visual data. Therefore, it was found that conducting a pilot test and collecting at least 24 hours of pilot data is highly beneficial. Test data aids researchers to customize data collection equipment to the target environment. For example, during pilot data collection it was observed that wide angle camera receives direct sunlight in the afternoon and makes it difficult to capture environment, the kiosk location is changed to solve this problem. Another example was a bright light source in front of living room camera, which affected the automatic exposure adjustment of the camera and caused dark images.

The kiosk is a heavy (30kg) and tall (2 m) equipment, therefore moving four of them from one location to another is a major task. In addition to transportation of equipment from laboratory to the participant’s house, carrying them inside the house is also challenging. Although, the risk of damaging participant’s property is high with large and heavy equipment, the weight of the equipment fixes it at desired position in the house.

After everything set up and data collection started, it is observed that there are synchronization problems with different cameras in the house. This was observed in pilot test data and resolved prior to actual data collection. The system is locally monitored with heart-beat software and remotely monitored with GPRS data line. The hourly reports give information about system health and ask for attention if necessary.

To give full control to the participant over his privacy, the contents of the data is not monitored during the course of the data collection. Data is stored locally on an external hard disk drive and removed at the end of the study. Participant is inquired about unwanted episodes of data; however he responded that he was comfortable with the data. Nevertheless, data analysis revealed that participant unplugged the data collection equipment for almost a complete day and stopped data collection on purpose. This suggests that instead of turning off a switch, unplugging the device entirely is more intuitive for the participant.

After the removal of the equipment and the data, maintenance tasks are started at the laboratory. Data is transferred to analysis computers and backed up in a secure server and the portable disk drives are prepared for the next study. The hardware is tested and reset for the next data collection task. In addition to these, batteries from wireless sensors are removed and marked based on their remaining capacities.

5.3. Case Study 2: The Design and Implementation of a Simple Sensor for Data Collection

In this study a simple sensor and data logger together with internal device logs are utilized to collect data on the utilization of a novel smart functionality of a dishwasher for domestic use. Sensor and data loggers were kept as simple as possible and focused on a single activity to achieve an affordable data collection. The study is a part of a larger user study that aims to observe and evaluate various functionalities of three dishwashers. The larger study was conducted at METU - UTEST Product Usability Unit.

5.3.1. Study Setup

The study is aimed to observe user interactions with a novel automatic dishwasher door, and user behaviors compared to interactions with traditional non-automatic dishwasher door. All study participants had previous experiences with dishwashers and their dishwashers were replaced by prototype dishwashers with automatic and non-automatic doors. There are 9 users with automatic doors in the test group and 20 users with manual doors in the control group. Dishwashers are instrumented with data loggers to collect data on interaction with the door and the interface events.

Internal data loggers aimed to collect user interface events and user preferences based on time of the day and wash cycles, in addition to internal data loggers, external data loggers were installed to observe the interactions with the dishwasher door. Internal data loggers are able to collect and synchronously transfer all digital information regarding the functionality of the dishwasher including the interface events, whereas external data loggers are designed to collect data specifically on dishwasher door usage.

Participants were visited 4 times during the study and interviewed in the last visits, the first visit was for implementation, the last was for interview and removal, the visits in between are solely for maintenance and data transfer. Participants were asked to respond interview questions about their dishwasher door usage, expectations from a smart dishwasher and satisfaction from the new dishwasher and its special functions.

5.3.2. Study Procedure

The aim of this case study is to observe the capabilities of a simple data logger and sensor kit on the evaluation of a specific activity for large sample sizes. Therefore a relatively large number of participants are required. Moreover, the study duration needs to be long enough to observe issues related to synchronous data collection in multiple sites.

Although user interaction with the product is intended to be observed with automatic data collection instruments, field visits are planned for collecting subjective representations of use and collecting contextual information. Starting with the first visit and the installation of dishwashers in participants' houses data collection is pursued for approximately 6 weeks for a participant.

5.3.3. Research Team

The study is conducted at METU/UTEST Product usability Unit. The research team consisted of three senior user experience researchers. Study procedure was designed and implemented collaboratively in the research team. Current researcher designed the simple sensor and the data logger couple and constructed the installation procedure for them.

The analysis of the data collected from the data loggers and data transmitters are also carried out by the current researcher. Based on the results of this analysis participants are contacted by other team members for their subjective responses.

5.3.4. Recruiting and the Participants

Participants are recruited by word of mouth and a total of 30 participants were recruited. Possible participants are identified and a screening interview was conducted on the phone. The participants were recruited according to the following criteria;

- Must have a previous experience with a dishwasher
- Uses dishwasher on a regular basis
- Must live in Ankara
- Must be available for home visits

For the test group 9 females and one male participant, for control group 18 females and two male participants were recruited. For test group the age range is from 37 to 66 and for control group the age range was from 23 to 65.

Participants were given the opportunity to buy the dishwashers at the end of the study for one third of the regular market price.

5.3.5. The Product: Smart Dishwasher

The product is a smart dishwasher that can detect external information such as water quality, hardness and pressure as well as dirt level and act accordingly. It can also detect various information regarding to the operation of dishwasher, such as; water leakage, which will result in the immediate stop of washing cycle. The primary functionality of the dishwasher that is under study is the automatic door that is responsive to the humidity inside the dishwasher. Dishwasher automatically releases the door at the end of the washing cycle for a 10 degree to enable natural cooling and drying of the dishes to conserve energy.

The product is a beta testing prototype which is almost ready for mass production. The dishwashers that are installed at participants' houses are fully functioning prototypes and installed by authorized service personnel.

5.3.6. Aims and Objectives of Dishwasher Study

The product that is under study looks like and functions like a regular dishwasher however it has an added functionality that is novel to dishwashing activity. Hence, the user research aims to observe the adoption and usage behavior of this new functionality compared to regular dishwashers. The new functionality is the automatic release of door lock at the end of the washing cycle to dry dishes with natural air flow and conserve energy. The door stays open until the user shuts it. Therefore, the product displays the end of washing cycle in a novel, more intuitive way.

The products that are installed in participants' houses are beta prototypes and similar to mass production versions. Hence the overall study is a summative study that aims to observe and evaluate a specific activity in terms of interaction. Understanding user habits for dishwashing cycles and understanding the match between user needs, everyday activities and product functionality is the major implication on data collection requirements. Instead of observing the complete everyday activities observing a particular activity, the utilization of the dishwasher door, is the focus of the data collection study.

5.3.7. Contextual Environment

Dishwasher study was also conducted in participants' own environments; however the contextual environment is not controlled with screening survey as in the FPLT study. The study was conducted in kitchen environments. The contextual environment for each participant is documented during the first meeting. Before visiting participants, it is decided that the clearance in front of the dishwasher is critical for the study and it is documented during the case study.

Additionally the presence of kids and pets are identified as another factor influencing the data collection equipment. In order to minimally invade contextual environment and minimize the effects of equipment in participant behaviors and activities it is decided to hide data collection equipment inside the dishwasher.

Figure 28 Sample Contextual Environments from Dishwasher Study

Six of the contextual environments which are all from the test group, are demonstrated in Figure 28. It is observed that dishwashers are located near the sink because of the dirty water outlet. The area around the sink is very active in terms of human circulation because most of the activities conducted in the kitchen are associated with water and the sink.

All of the participants except U03 (Figure 28) has enough clearance for the door to open in full length. U03's dishwasher door touches kitchen door and do not open at full length. And U07's dishwasher door cannot be opened together with the oven door. The door opening clearances share the same space and touch each other when tried to open together. Besides physical environment the social environment also show variations among the participants. Out of 30 households, 10 of them are couples, 4 of them are families with one child, 6 of them are families with two children, 5 of them are singles, 2 of them are housemates, 2 of them are single parents with one child and one of them is a couple with a senior in the house. Within this social context three participating households have pets (U12: dog, U23: cat, U27: cat) and three of the households (U23, U25, U29) have children under 6 years old.

5.3.8. Data Collection Equipment

The main challenge in observing the utilization of a dishwasher is the frequency and timing of use as dishwashers are utilized once in two days on average and at any time of the day based on the amount of dishes. Therefore, observing the interaction requires a tool that will be inactive most of the time and detect simple state changes of the door.

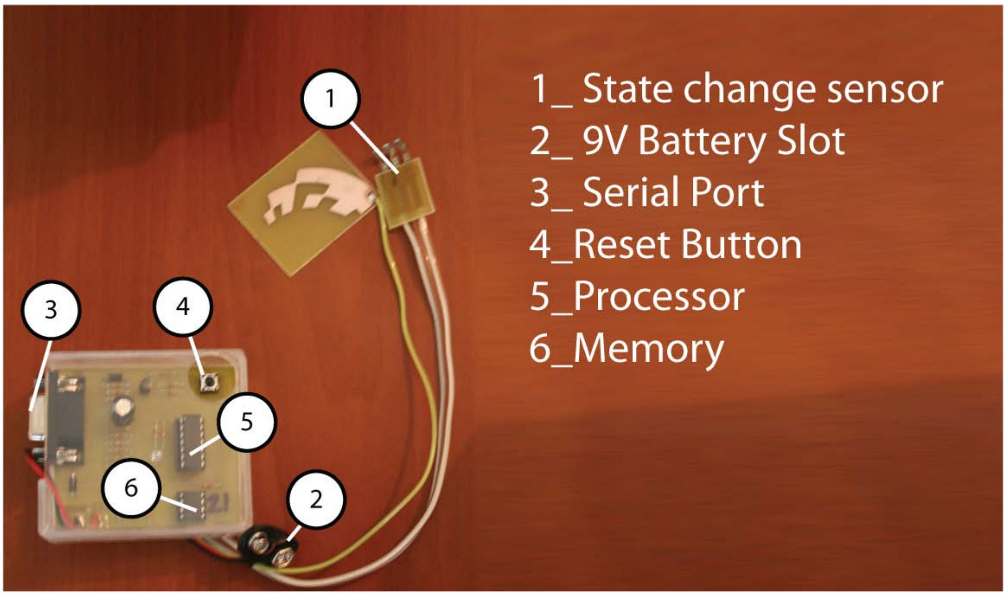


Figure 29 Data logger and sensor couple for case study 2

Based on the characteristics of the product, contextual environment and the aims of the study, two separate data collection equipments were utilized for data collection. The first one is a data transmitter that transmits machine logs to an FTP server and the second one is an external sensor and data logger couple that is attached to the dishwasher externally.

The data transmitter is developed by the dishwasher manufacturer to collect both technical performance data, such as water temperature, hardness, pressure, washing cycle timing, machine decisions, as well as user interface events such as key presses and menu selections. It has a cellular GPRS modem built in it and sends machine logs to an FTP server in a proprietary format. A software tool developed by the manufacturer visualizes the collected data and provides information about wash cycles and user preferences over the wash cycles. All of the test group and 9 of the control group dishwashers are equipped with data transmitter devices.

The external data logger and sensor couple is developed by the researchers at METU – UTEST product usability unit based on Mondo Technology Skylar 2 (Monat, 2011). Data collection equipment has the basic parts, processor, data storage, sensor and computer interface at the very simple formats. It has certain limitations such as storage size and battery consumption (Figure 29). The data logger checks the sensor every millisecond and looks for a change if the state changes in the sensor such as door movement, the data logger records the state change with time information.

The data logger can store 10 days of data on its memory and it is supposed to work 8 days with a fully charged 9V battery. It is attached to dishwasher door besides the door hinge (Figure 30). The sensor part of the equipment is explicitly visible; however the data logger and battery parts are hidden inside the dishwasher. The plastic cover under the dishwasher door is removed and the data logger and the battery are stored inside this plastic cover. All of the dishwashers are equipped with external data loggers.

Figure 30 Sensor installation

A profile template is cut from foam board to standardize sensor installation, this foam board template made sensor installation quicker and standard for each dishwasher. Once the sensor is installed, its battery is connected and the sensor is reset to start collecting data.

The dishwasher door opens 90 degrees but able to stop at a predefined location which is 10 degrees. When the dishwasher releases the door lock the door opens 10 degrees and stays at that location to enable natural drying. Therefore, the sensor is set to 10 degree increments, to identify the state of the door. The sensor is able to detect whether the door is open, closed or ajar. In addition to the state of the door sensor is able to detect the direction of the movement, whether the door is closing or opening.

5.3.9. Data Collection and Analysis

The overall user research study was scheduled to have a six week observation period; however observation and comparison of automatic door functionality is scheduled to have a one month data collection period in the overall study schedule. Dishwasher use is observed with device logs and external sensor and data logger. It is decided to collect wash cycles and couple it with the door usage and have an overall understanding of how participants use dishwashers. With this overall understanding, it is expected to deduce loading and unloading habits of both test group and control group at the end of the study.

The study started with the installation of dishwashers by an authorized service team. They made appointments with the participants, installed dishwashers and debriefed participants about the characteristics of the dishwashers and the data collection devices. It took 2 weeks to complete installation of 29 dishwashers (one participant was on vacation and her dishwasher is installed at the 4^{th} week of the study). The installation team makes appointments in 2 hour frames as they cannot anticipate the local physical conditions (distance from power plug, dirty water outlet, cabinet dimensions etc.), therefore eight of the appointments are rescheduled. The logistics planning of such a big sample size requires backup plans in various levels. At certain times the installation crew skipped some appointments or arrives earlier than expected because of uncontrolled factors, such as traffic and rescheduling requests from participants.

One week after the installations research team started field visits to download data from the external sensor and data logger and replace batteries. Participants were not surveyed at these visits. After first round of visits second field visits are started and after that third round of field visits are conducted. For 29 participants 4 visits per participant is achieved. Although each visit takes 5 to 10 minutes of time planning and performing these field visits take extensive amount of time.

On the fourth visit participants are surveyed about their utilization of the door by a post test interview. The interview asked their experiences with the door mechanism for the test group and expectations from such a mechanism to the control group. Their responses to the interviews are compared to the digital internal and external logs.

There have been a couple of issues related to the data collection equipment. First of all the data transmitters that are expected to send real time data to an FTP server did not performed as expected and caused a considerable amount of data loss. In addition to these, participant interviews showed that some participants developed an unanticipated usage habit with dishwasher doors which is beyond the data collection capabilities of external data logger. These issues will be presented in detail in the following section.

5.4. Findings of Case Study 2

The scope of the case study 2 is more focused compared to case study 1. Case study 2 focuses on a single activity and a specific functionality of a more conventional product. Case study 2 has a relatively large sample size (N=30) for a domestic data collection study and the duration of data collection is 4 weeks which is again a relatively long duration for an in context user study.

The findings of the case study will be presented in line with the domestic data collection method under data collection methods, equipment design and implementation titles.

5.4.1. Findings of the Dishwasher Door Study

Case study 2 aims to observe the effects of a new functionality on the dishwashing habits of participants. In order to observe these effects it is decided to observe and compare participants with new dishwashers and conventional dishwashers. The following data is collected for both of the groups;

- The state of the door; opened, closed or ajar
- Time and duration before state change
- Number of interactions with dishwasher
- Time and duration of interaction with the door

The state of the door (opened, closed, ajar) when there is no interaction with the door is compared between test group and control group to observe differences between groups. Table 4 demonstrates the data on the state of the dishwasher doors both in test group and control group. The ratio of the duration of slightly open doors against data collection duration presents that except three participants (U23, U25 and U03), participants in the test group left dishwasher door ajar in extended durations compared to control group. Participant U03’s dishwasher door is not able to open at full length and it is located in front of the refrigerator (see section 5.3.7). U25 has two children and U23 has two children and a cat (see section 5.3.7). These physical and social contextual characteristics might have effected participants' utilization of dishwasher door.

Table 4 Data on state of the dishwasher door

Test Group (Dishwashers with Automatic Door)									
Participant	U03	U06	U25	U07	U09	U20	U23	U12	U21
Data Collection Duration (min)	9269	11712	10295	11181	11800	8562	10154	11166	1752
Door Ajar(min)	82	1256	17	7521	2189	7521	5	2503	247
Door Ajar /Data Collection	**0,9**	**10,8**	**0,2**	**67,3**	**18,6**	**87,8**	**0,1**	**22,4**	**14,1**
Control Group (Dishwashers with Conventional Door)									
Participant	U01	U04	U15	U16	U28	U26	U08	U18	U11
Data Collection Duration (min)	9269	8522	3907	10521	12776	8376	4512	8631	1436
Door Ajar (min)	82	0	10	28	16	78	4	25	9
Door Ajar /Data Collection	**0,9**	**0,0**	**0,3**	**0,3**	**0,1**	**0,1**	**0,1**	**0,3**	**0,6**
Control Group (Dishwashers with Conventional Door)									
Participant	U05	U10	U13	U14	U19	U24	U27	U29	U17
Data Collection Duration (min)	8526	8735	9730	8111	13230	12949	9038	8173	318
Door Ajar(min)	17,0	0,0	13,0	0,0	10,0	126,0	0,0	0,0	0,0
Door Ajar /Data Collection	**0,2**	**0,0**	**0,1**	**0,0**	**0,01**	**0,1**	**0,0**	**0,0**	**0,0**

Figure 31 demonstrates the average durations of slightly opened state of dishwasher doors across test and control groups. Test group left their dishwasher door ajar for significantly longer durations of time compared to control group. Moreover, it is inferred from the data that test group left their dishwasher doors ajar for the 25 percent of the data collection duration on average.

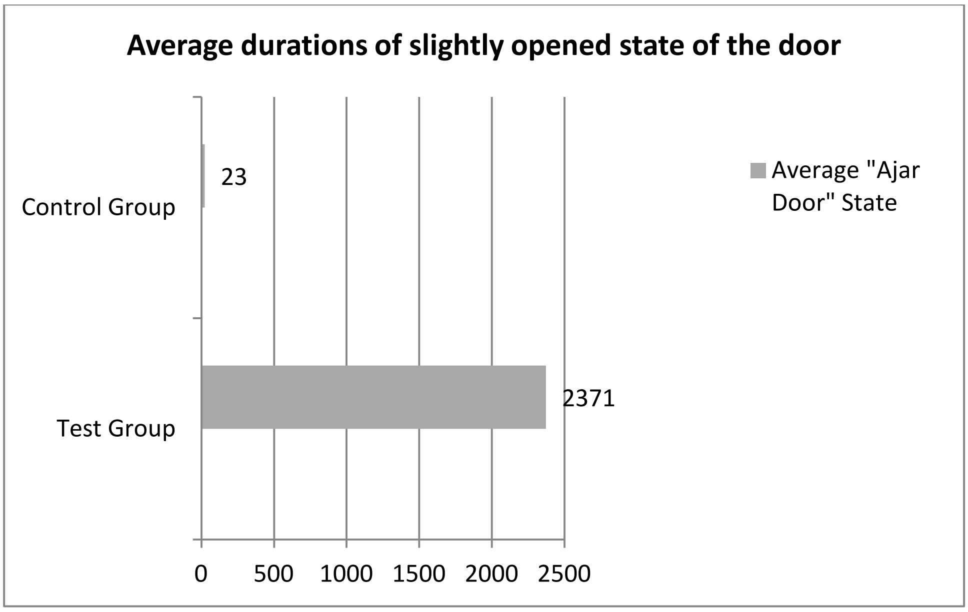


Figure 31 Average durations of slightly opened state of the door

Test group participants’ dishwashing activities are evaluated deeper to understand whether they are intentionally opening the doors by themselves or the door stays open after automatic release of the lock. The wash-cycle information (captured with internal logs) is matched with door state (captured with door sensor) and it is inferred that dishwasher doors are left open after the automatic release and participants leave it open for a designated time of their preference (Table 5). Participants do not close the door immediately after the end of wash cycle.

Table 5 Duration of ajar door after each wash cycle for test group

Test Group (with automatic Door) Duration of open door after each wash cycle in minutes						
	U03	U06	U07	U09	U20	U12
Wash Cycle 1	72	4	50	7	22	14
Wash Cycle 2		5	439	371	30	4
Wash Cycle 3		63	96		13	
Wash Cycle 4		1125	19		124	
Wash Cycle 5			5		44	
Wash Cycle 6			84			

Another identifier for the user behavior with the dishwashers is the number and duration of interactions with the dishwashers. In order to evaluate interactions, raw data is annotated based on 240 second intervals, which means that any interaction after a 240 second period is coded as a separate interaction.

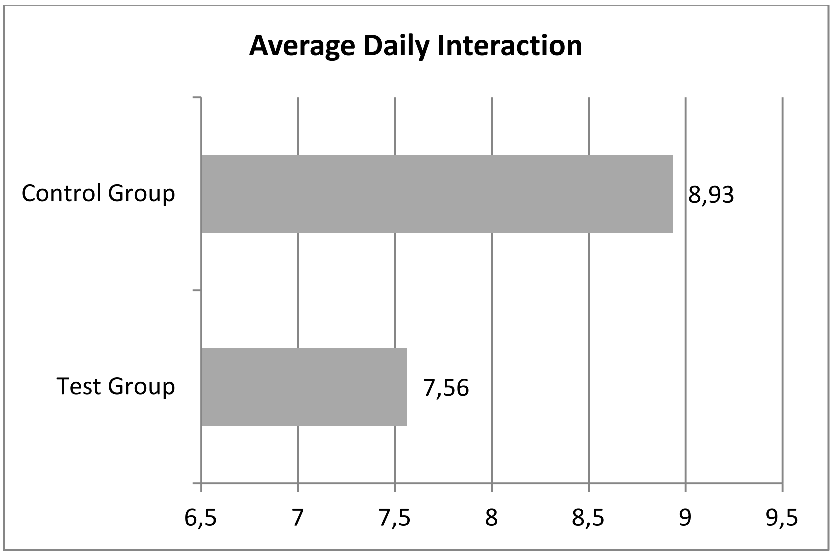


Figure 32 Average number of Interactions per day

Both average number of interactions (Figure 32) and average interaction durations (Figure 33) for test group are lower than control group. Test group participants interact fewer times and for shorter durations compared to control group. This faster and more effective interaction might be due to the slightly opened door.

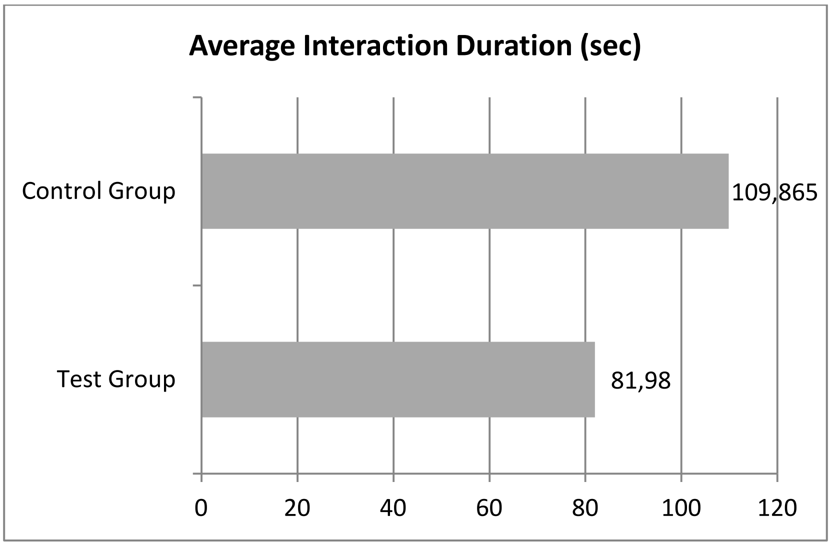


Figure 33 Average interaction durations.

At the end of the study, participants were asked to respond to an interview about their dishwasher door usage. Responses given to this interview were demonstrated in Table 6, according to the table, participants with automatic door are more willing to leave their dishwasher door ajar. In addition to this they are less willing to fully close the door when the door is ajar.

Table 6 Post test interview responses

Post Test Interview Responses	Test Group	Control Group
	(1 Never, 5 Always)	
I keep the door closed when there are dirty dishes inside the dishwasher	3,50	4,64
I keep the door closed when there are clean dishes inside the dishwasher	3,00	4,14
I will close the dishwasher door if I see it slightly opened.	3,50	4,43

5.4.2. Findings Related to Data Collection Method

Automatically collected logs and post test interviews are utilized for data collection in case study 2. The study heavily relied on data collection equipment for creating a representation of use in domestic environment; however it was observed that automatic data collection equipment performed lower than expected. Researchers aimed to collect real time data from contextual environments and modify interviews accordingly, nevertheless one of the data collection equipment which was responsible to record user interaction based on internal device logs failed to efficiently transfer required data.

Failure to collect dishwasher usage data resulted in complexities for the interpretation of data received from external data logger. The data logger captured opening and closing events and the state of the door, however without interaction data it is problematic to infer whether the participant is loading or unloading the dishes.

The failure of the data transmitter can be explained by the limited reliability testing conducted in contextual environments. At the laboratory the dishwashers are installed in a spacious environment, however at the domestic environments they are installed under the bench and against the wall. One of the reasons behind the loss of communication between data collection tool and the server is the loss of signal at data collection location. Combined with the metal cage of the dishwasher, the walls and the bench around the dishwashers limited cellular GPRS connectivity with the server to transfer captured data.

Utilizing two separate data collection tools prevented complete loss of data, since the external data logger attached to the door continued data collection. However, utilizing two separate data collection tools created synchronization problems. Although it is not critical for this study, it might be a good practice to use a central time server to synchronize all data sources.

5.4.3. Findings Related to Equipment Design

Both of the data collection equipment utilized in dishwasher study is intended to operate standalone without any outside intervention. However, there have been reliability issues in terms of their operation. Data collection equipment diagram for a single dishwasher is demonstrated in Figure 34.

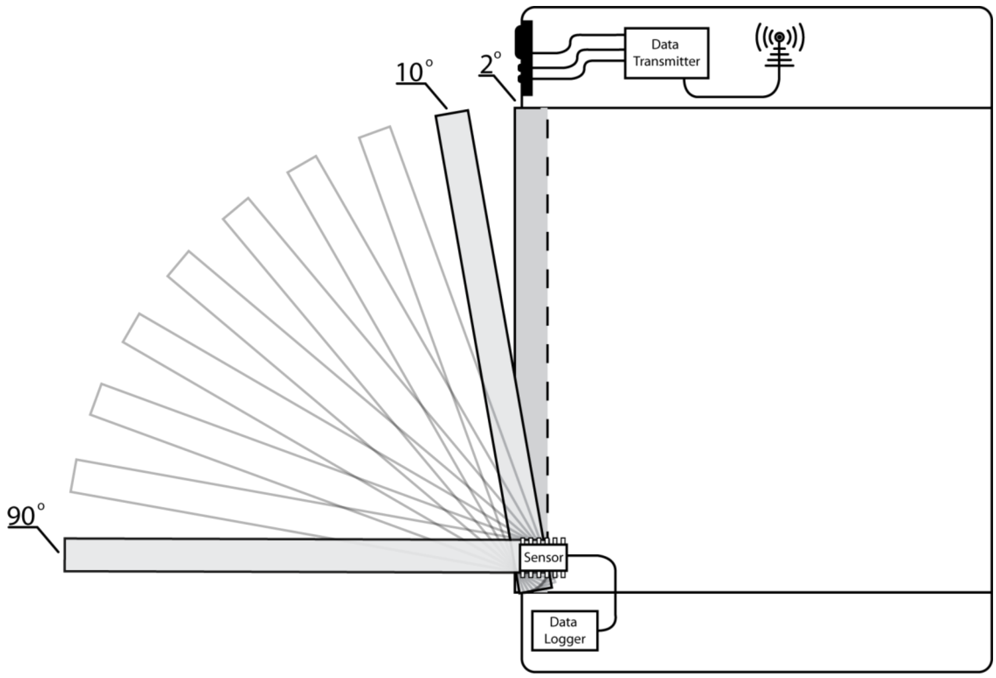


Figure 34 Data collection equipment diagram

Internal data logger and transmitter is a complex equipment that collects device logs stores them temporarily and sends them to an FTP server via cellular phone network utilizing GPRS technology. Researchers need to download this data from FTP server and visualize the data using a propriety software tool. Flawless operation of this tool depends on a number of external technological contextual factors such as cellular network coverage, FTP server authentication, continuous running of FTP server and network connectivity of the FTP server.

During data collection it is observed that cellular network coverage and flawless operation of FTP servers created problems with data transfer. Out of 19 data collection equipment only 6 of the data transmitters are able to send data to FTP server. FTP server is configured to provide data as soon as it receives it; however, due to network connectivity problems synchronous sharing of data cannot be achieved for 3 weeks.

On the other hand, the data sent by the 6 dishwashers (4 test, 2 control group) provided detail rich interaction data including user preferences and dishwasher state. The data collection and transmission tool served as a proof of concept that even consumer white goods can provide usage information for user research studies with their built-in capabilities.

The external data logger is installed onto every dishwasher both in the test and control groups. It is designed to collect data on the interaction with the dishwasher door by capturing the angular movement of the door. The tool is able to record angular movement in 10 degree increments. The tool gets its power from a 9 volt battery. The pilot tests in the laboratory showed that a fully charged battery is able to power the device for around 1000 opening and closing events of the dishwasher and this is acceptable since the memory of the device is not sufficient for that amount of events.

With the battery and memory limitations researchers scheduled field visits every week to be on the safe side. Before installation all the equipment is given to the authorized installation team and they are trained for the installation of sensors. After the first round of visits it is observed that installation team used very low quality batteries with the data loggers and an average 20 hours of data is recorded per participant, after the first round, batteries are replaced by high quality batteries and the average data collection time with a single battery increased to 145 hours.

External data collection equipment is designed to capture movements of dishwasher door in 10 degree increments as the dishwasher door automatically opens and stops at 10 degrees from the closed position. And this position is referred to “ajar” or “slightly opened” during the interviews. However, during the in context interviews some participants refer “ajar” or “slightly opened” state of the door when there is a small gap between the closed position (Figure 35). This term confusion caused misunderstandings during interviews with the control group as they have not seen the dishwasher with automatic door.

After the in context post test interviews it is found that participants refer a two degree gap as “slightly opened” or “ajar”. Being not aware of such a usage the data collection tool is not designed accordingly and missed the two degree opened state of dishwasher doors. Although this issue is not technical, it demonstrates that designing a custom tool for data collection requires a thorough analysis of target activity.

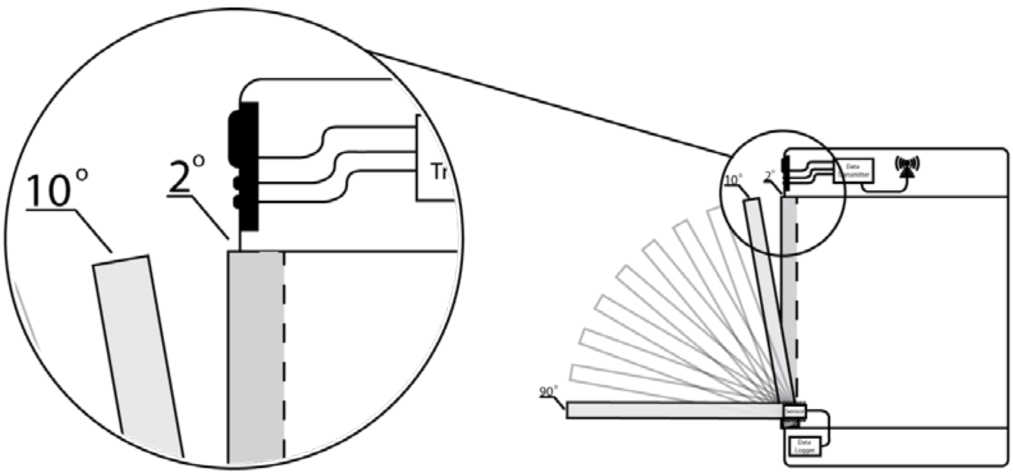


Figure 35 Researcher's and participant's representation of "slightly opened" door

5.4.4. Findings Related to Implementation and Deployment

The data collection equipment was attached to the dishwashers and did not require any installation efforts at the context, therefore the implementation and deployment procedure for the data collection study did not create issues except the appointments of field visits.

The design of the data collection equipment required weekly visits to participants and the sample size for the study is large compared to in context user studies (Kalof, et al., 2008). During the course of four week data collection 4 visits per participant is planned, which makes 120 visits in total. Participants are distributed in a very large geographical area and each round of visits takes approximately 500 km of trip distance. Besides that, full time worker participants asked the visits to be between 6 pm and 8 pm, which decreased number of field visits per day.

Weekly field visits increased the costs associated with data collection in terms of financial costs, researcher time and participant time. Although building a robust and reliable standalone data collection tool require considerable financial investment, it can decrease field visits dramatically which in turn decreases the costs associated with the data collection.

The field visits took 5 to 10 minutes in average and do not require actual user to be at home. During the field visits researcher downloads the data and leaves the house. External data collection tool is located under dishwasher door at the bottom of front panel. And it is easy to remove it and connect to a computer for data transfer. However, this simple operation raised issues at participants with children under 6 years old and participants with pets. Children and pets are curious about the colorful cables beside the dishwasher and tried to remove data collection tool from the plastic cover. In three participants data collection tools are dislocated and at two of the participants the cables are broken. This suggests that data collection tools must be embedded in the product or environment and invisible to the inhabitants.

5.5. Iteration of Domestic Data Collection Method with Respect to Case Studies

Proposed domestic data collection method is revised based on the findings of two case studies by comparing anticipated relationships between independent and dependent variables against observed relationships in case studies.

A detailed overview of how independent variables expected to affect dependent variables in terms of equipment design (ED), data collection (DC) and implementation (Imp) in proposed method is presented in Figure 36. Figure 37 demonstrates the outcomes of first case study and Figure 38 demonstrates the outcomes of second case study. Variables in proposed method (Figure 36) are replaced by actual values in case study diagrams (Figure 37, Figure 38). In Figure 37 and Figure 38 findings related to the variables are printed with red italic font.

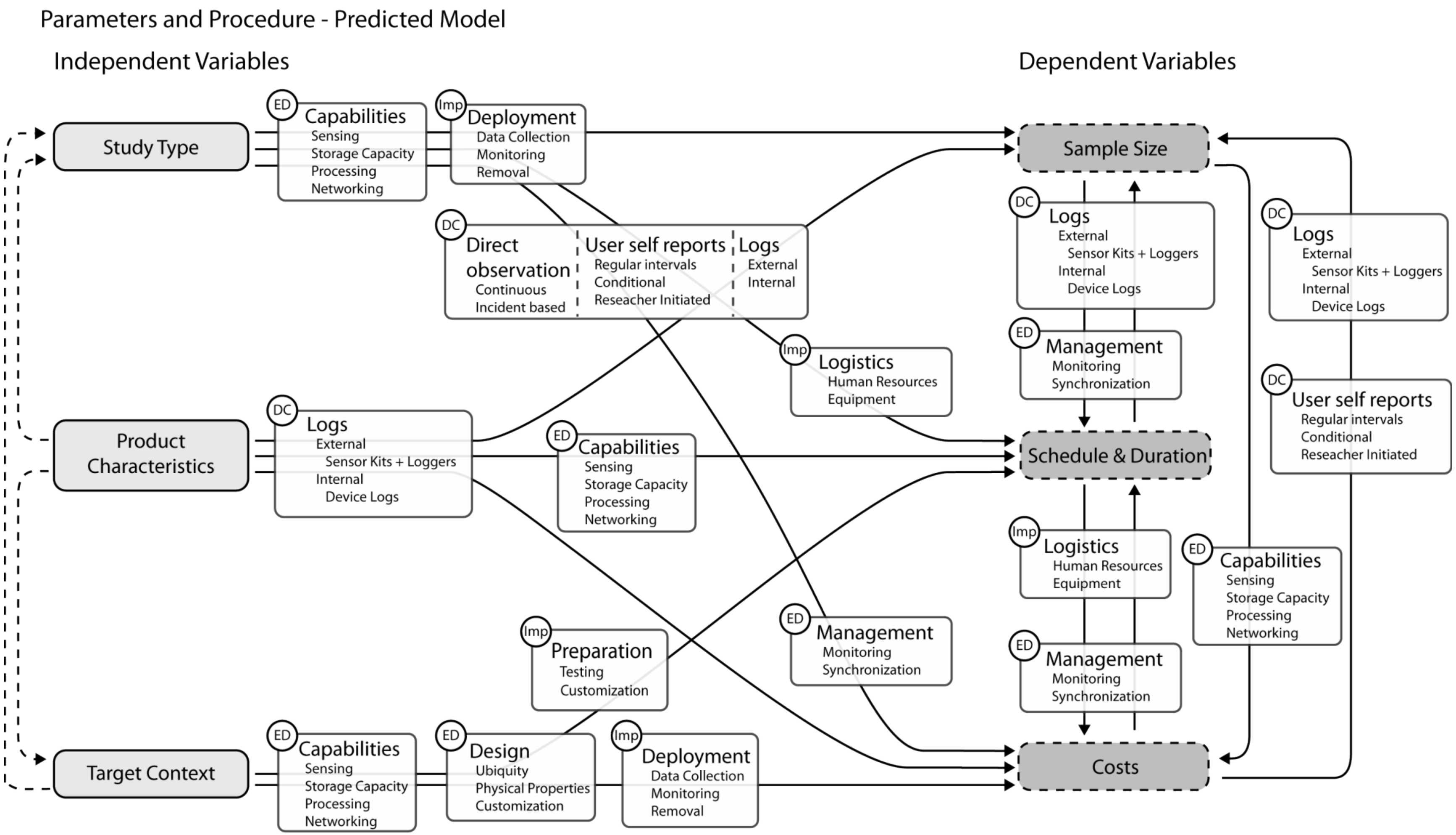


Figure 36 Proposed Domestic Data Collection Method

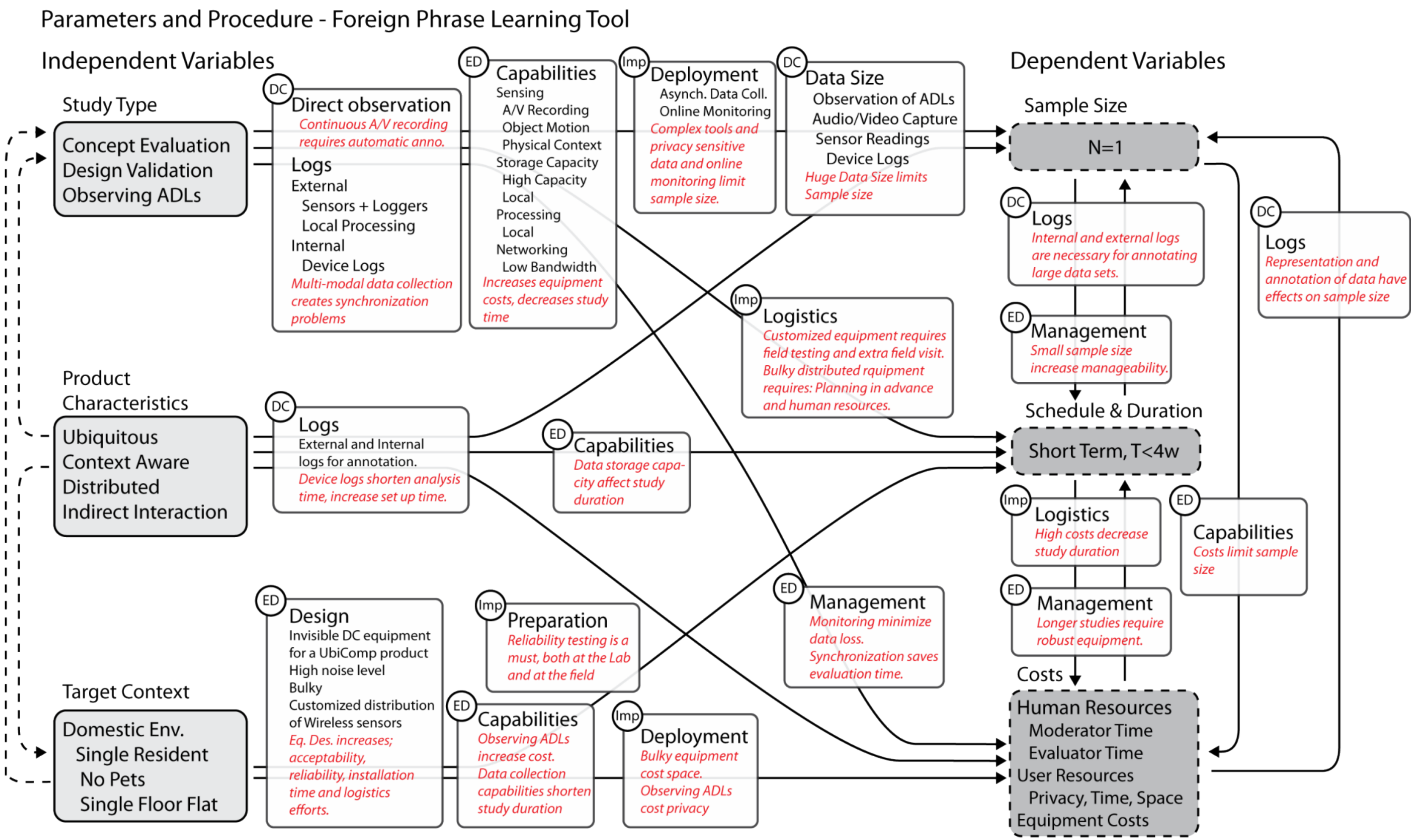


Figure 37 Realization of Domestic Data Collection Method in FPLT study

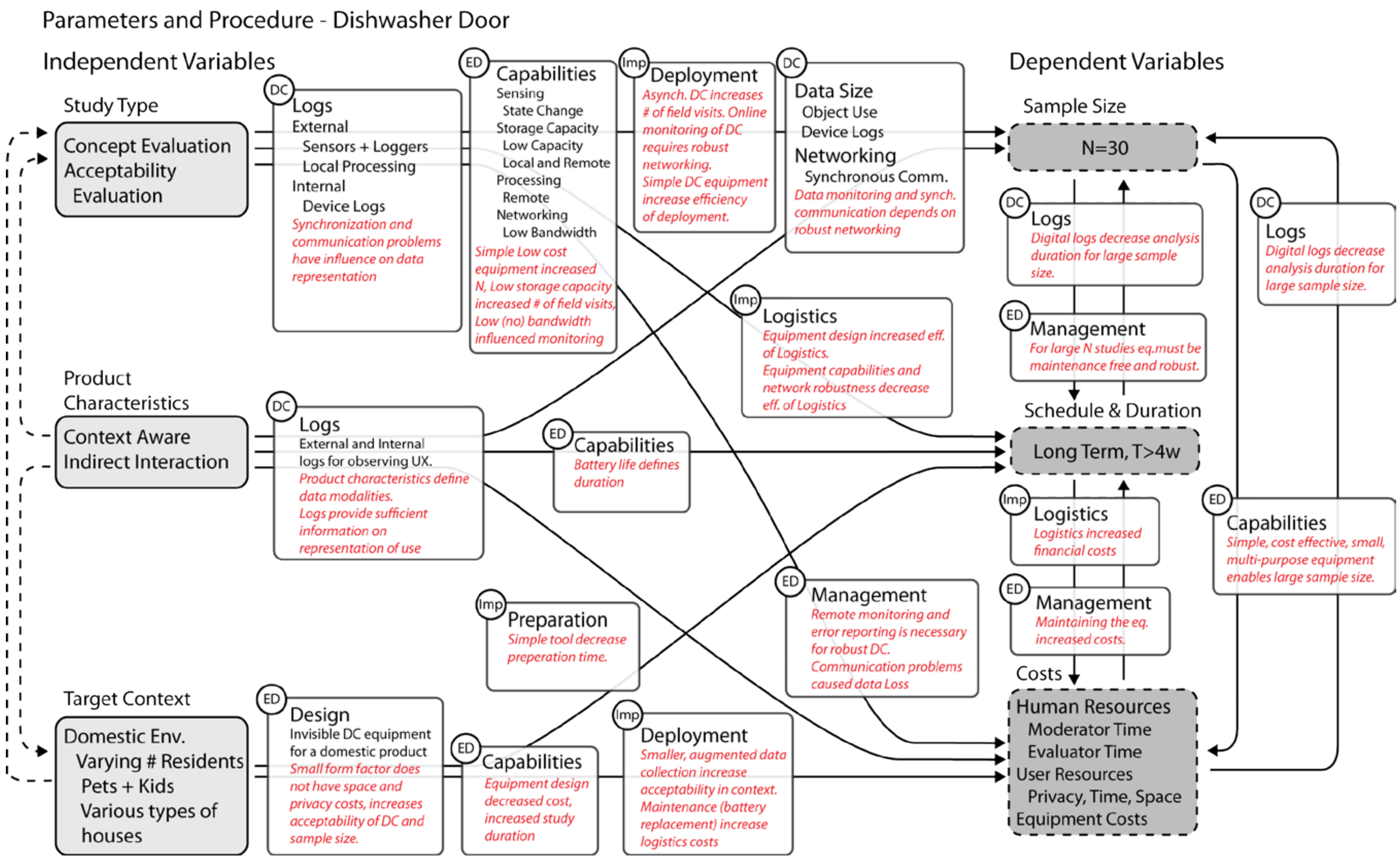


Figure 38 Realization of Domestic Data Collection Tool in Dishwasher door study

5.5.1. Implications of Study Type on Sample Size

In the proposed method the type of a user research study is expected to have effects on sample size in terms of data collection equipment's capabilities and study deployment procedure However, in both case studies it was observed that besides deployment procedure and equipment capabilities, observation method is another factor that has effects on sample size (Figure 39).

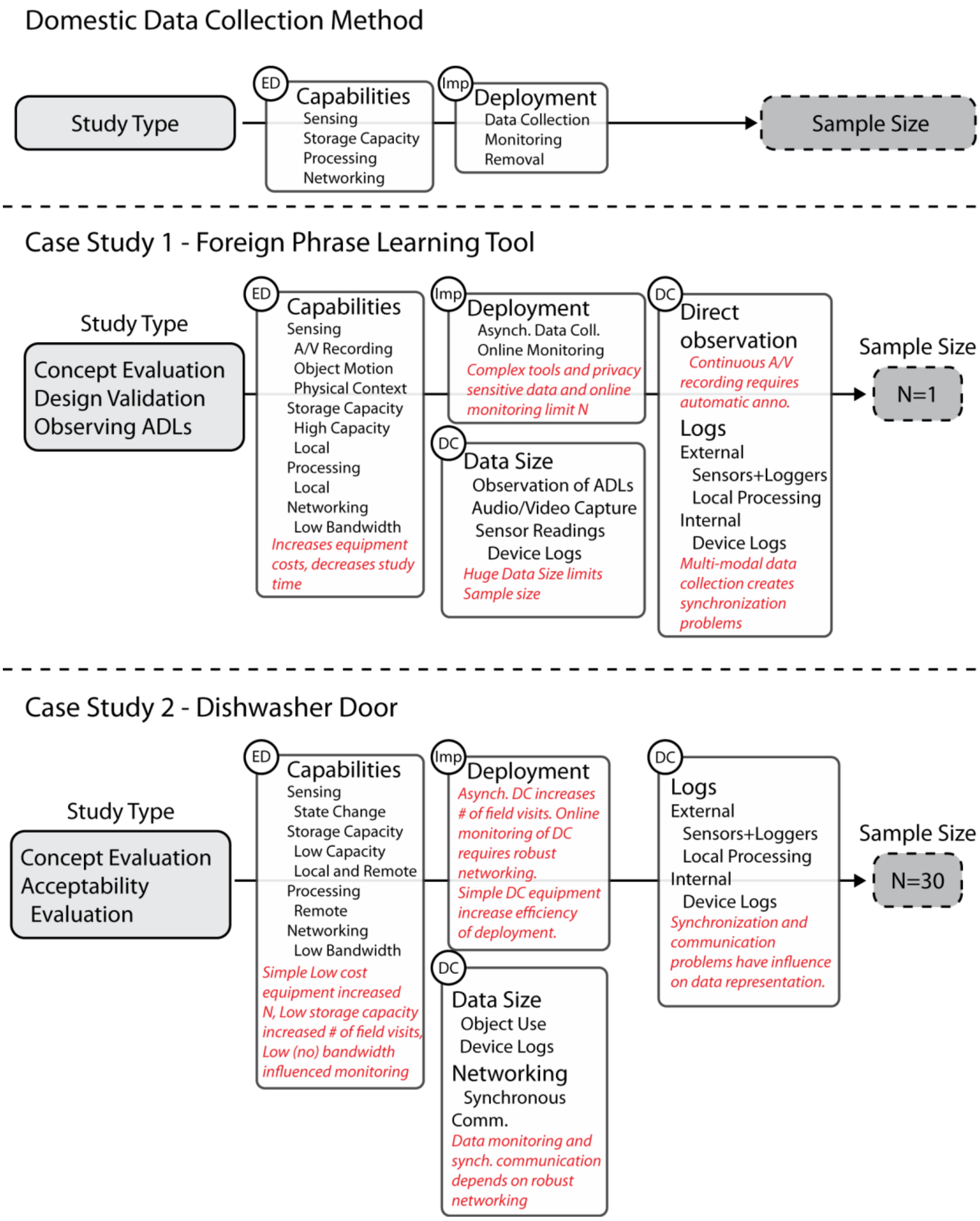


Figure 39 Implications of Study Type on Sample Size

The type of study in case study 1 and case study 2 is similar in terms of concept evaluation, other than that, the first study aims to validate design and observe activities of daily living and the second case study aims to evaluate a new product concept and acceptability of a new function. In the first study the evaluation was formative and the product is at the prototype stage and it was the only working sample available, hence the sample size is set to one participant.

The data collection equipment utilized in the first case study is a technologically advanced and ubiquitous tool. The system is large in shape and custom made out of off the shelf products. Constructing the prototype of data collection tool was financially expensive, hence; its deployment is limited to a single participant.

However, equipment utilized in the second case study is a simple, affordable and easy to manufacture custom made tool. Therefore it is deployed at 29 participant houses and enabled to collect data from a larger sample.

Data generated from the first tool was more than 700 Gigabytes; however data generated from the second tools is around 700 kilobytes from 29 participants in total. Handling, annotating and sharing the data from first study was burdensome even for one participant. On the other hand annotation of second case study's data was smooth for 29 participants.

Findings related to the study type can be summarized as follows;

- Studies that utilize direct observation require advanced sensing, storage and processing functionalities of data collection equipment.
- Utilizing tools that require longer setup times, monitoring and management limit number of participants for a user research study
- Huge amount of data per participant limits number of participants and number of simultaneous data collection studies.
- Automatic annotation of A/V data might decrease evaluation time and increase number of participants.
- Asynchronous data collection and monitoring increases number of field visits; hence decreases manageability of participants.
- Synchronization and communication problems have influence on digital representation of data

5.5.2. Implications of Study Type on Study Duration

The proposed method assumes that study type have influence on schedule and duration of a study in terms of equipment capabilities, deployment procedure, observation method and logistics. However, it was observed that the deployment procedure is not directly related to study duration. In the first case study the storage capacity of the equipment defined study duration, on the other hand in the second study battery power defined the duration of the study, which means that technical capabilities of data collection equipment is effective on the duration of case studies.

In the first study the main reason behind the shortage of storage capacity was the observation type for which audio video data was utilized (Figure 40). Although, there is plenty of storage capacity (4Tb) audio/video data consumed it almost in a week.

In Figure 40, comparison of anticipated method against results of first and second case studies in terms of study duration is presented. During the first study logistics of data collection equipment required advance planning, such as truck rental and an extra field visit due to its large physical dimensions and heavy weight.

Findings related to study type and duration of the study can be summarized as follows;

- The frequency of field visits in studies that require standalone data collection is defined by technical capabilities of data collection equipment. Higher capacity storage devices and batteries leads to longer standalone data collection and less field visits.
- Studies that require installation of highly customized equipment might take longer than expected to start data collection as custom installations require thorough pilot data collection at the field.
- Attaching data collection equipment to the product under study and installing them together increases the efficiency of logistics and decreases duration of field visits.

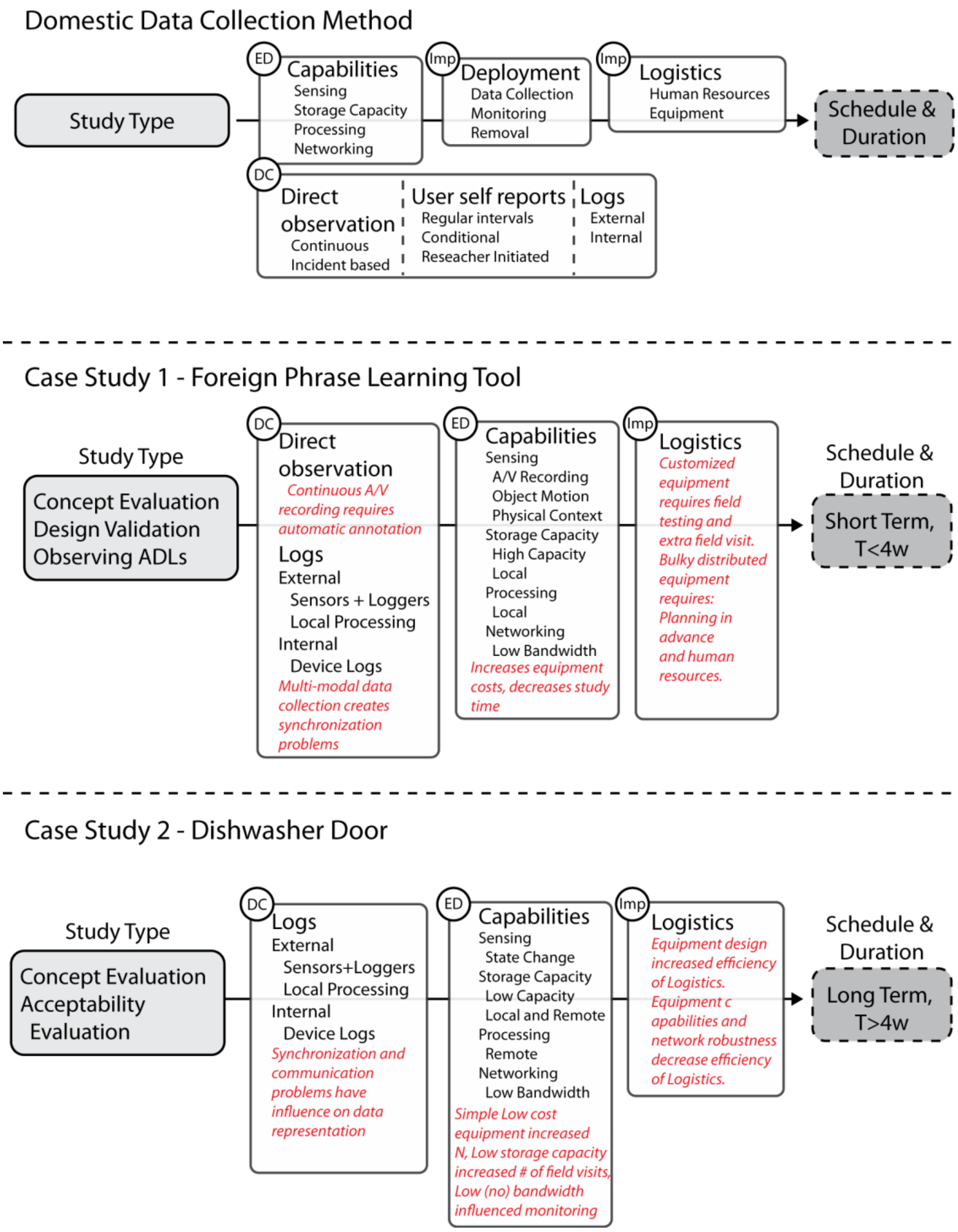


Figure 40 Implications of Study Type on Study Duration

5.5.3. Implications of Study Type on Costs

Costs associated with human resources, participants and equipment are all covered in case studies and the proposed method anticipated that costs will be associated with the study type in terms of equipment capabilities, observation type, deployment and management procedures (Figure 41).

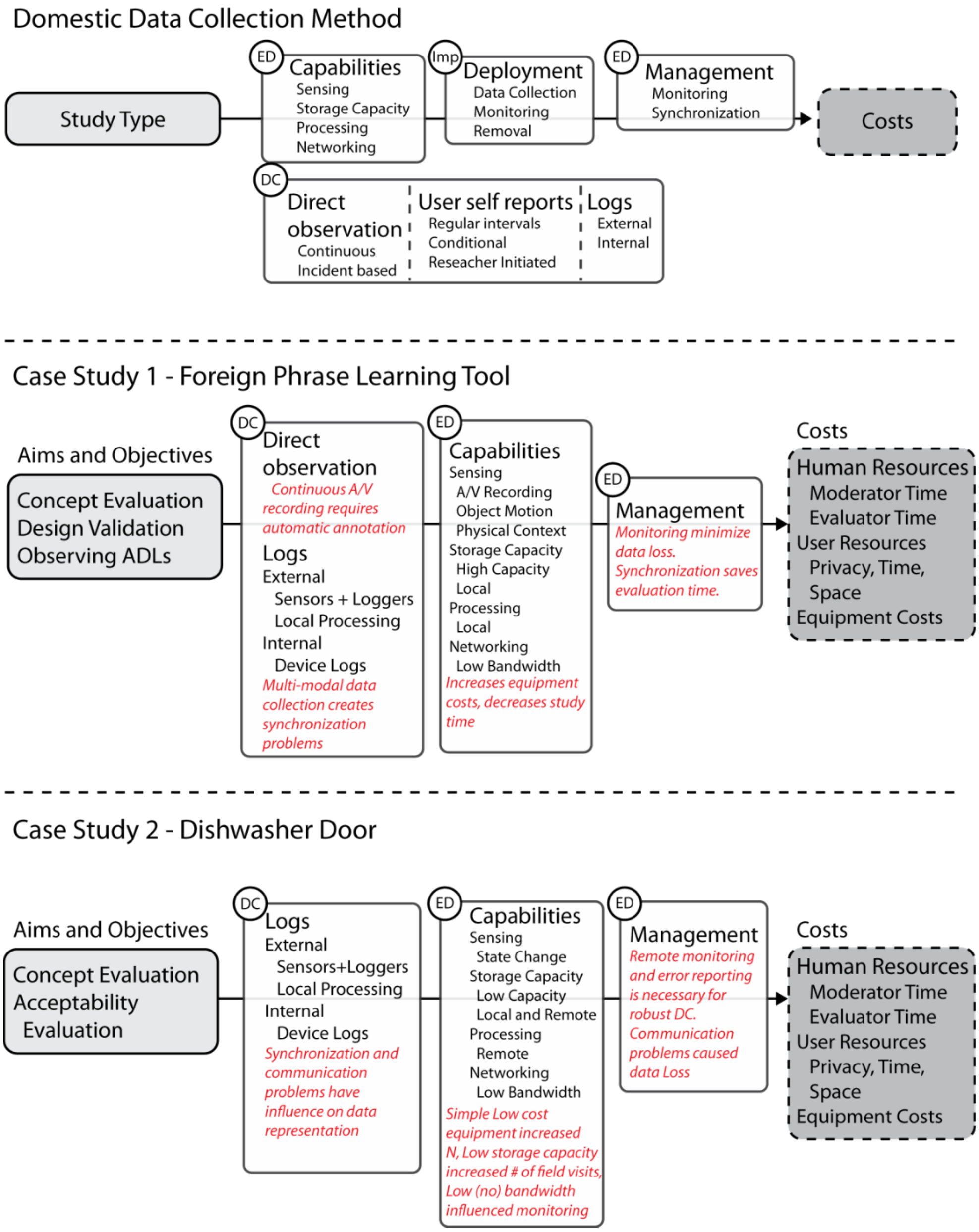


Figure 41 Implications of Study Type on Costs

The findings of two case studies demonstrated that data collection method of the study whether it is direct observation or data logging, is the main factor that utilize human resources. Evaluation of video data required evaluator time in the first case study, whereas external usage logs of second case study required shorter durations for evaluation in total for 29 participants, compared to single participant of first study.

In both of the studies equipment capabilities are associated with financial costs. Equipment costs in first case study is around 7000 USD for one participant, whereas equipment costs for second case study is around 20 USD for each participant. However, limited capabilities of data collection equipment and larger sample size in the second case study caused logistics costs to be much higher than the first case study.

For the first case study the study type required audio/video observation throughout the environment, which demanded full disclosure of participant's everyday life, however in the second study only device logs were utilized and the cost of the study associated with the participant in terms of privacy was very low. For example; during the first round of field visits of second case study, researchers asked to visually document participants' kitchen environments, however 3 out of 29 participants rejected researchers' requests to photograph the environment because of privacy reasons. The second case study was focused on a single activity and the acceptability of that kind of study was higher among participants.

The findings related to study type that influence costs can be summarized as follows;

- Studies that require complete observation of the environment require ubiquitous data collection equipment that has high-end sensing, storage, processing and networking capabilities which in turn increase financial costs associated with the study.
- Automatic annotation of usage data with sensors decreases evaluation and decrease costs associated with human resources. Whereas, high-end technological tools require the presence of technical personnel for possible failures and updates, hence increase human resources costs.
- Complete observation of the environment requires full disclosure of private life and has privacy costs at participant side.
- Digital representation of everyday routine of participants requires sensors and computers to be placed ubiquitously in the house environment, hence have spatial requirements and costs for the participants.

- Study procedures that iterate based on the real time data and user self reports during the study requires data monitoring and networking capabilities that increase financial costs and costs associated with human resources.

5.5.4. Implications of Product Characteristics on Sample Size

It was predicted that product and activity characteristics have effects on sample size in terms of data collection capabilities of equipment and deployment procedure (Figure 42). However, both of the case studies demonstrated that data collection method has also effects on sample size in terms of equipment design and data analysis. First case study generated around 600 Gigabytes of data even for a single participant. The second study generated only a small amount of data which is focused on a single activity and interaction.

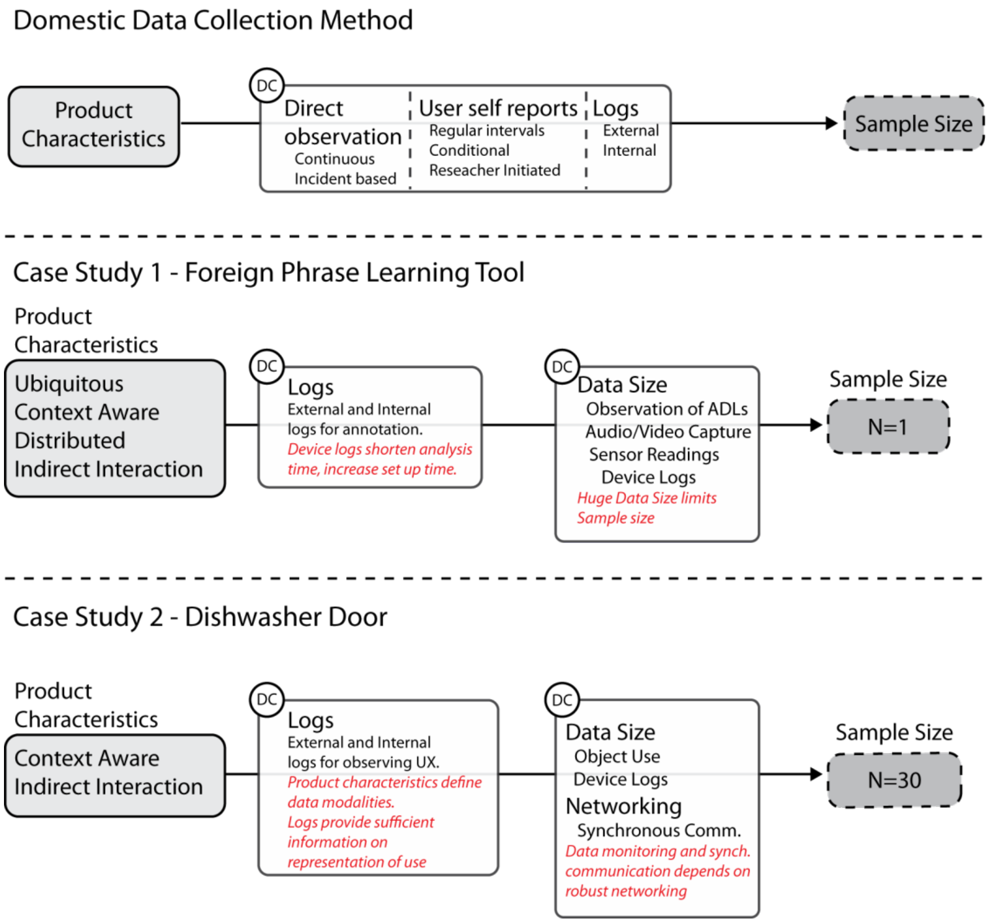


Figure 42 Implications of Product Characteristics on Sample Size

Ubiquitous and distributed nature of the product in first case study increased the installation and removal durations for the study and in turn decreased the sample size. Moreover, the product under study was an early prototype without any other sample; consequently the sample size is set to one. In the second study the products were final prototypes before mass production and it was possible to increase sample size.

The findings of the case studies demonstrated that product characteristics influence sample size in terms of;

- Ubiquity; products that are embedded in the environment have natural ways of interaction, hence requires direct observation of the user, which in turn decreases sample size.
- Device Logs; devices that are able to internally record and share interaction events and contextual factors might increase the sample size in a cost effective manner, as they will relieve dependence on external data collection equipment.
- Fidelity of the product; products that are designed as proof of concept, early prototypes or final prototypes define the sample size as their requirements for user research studies are different

5.5.5. Implications of Product and Activity Characteristics on Study Duration and Schedule

Proposed method assumed that product and activity characteristics might influence study durations and schedule in terms of utilization of device logs and designing the data collection equipment with time saving features (Figure 43).

However, the case studies showed that management of equipment during data collection process is also an identifier of study duration. If unmanaged, the error rates of data collection equipment increases and shortens data collection durations because of data loss. In order to support standalone long term data collection, equipment must be robust and maintenance-free. For example, it should not be dependent on battery power or tight storage limits. If battery is necessary, devices must be supported with batteries with a security factor of two. There was more field visits per participant in the second study then the first due to the low storage capacity and limited battery capacity of data collection equipment in second study.

The product in the first case study is designed for language learning during the course of everyday actions. It is intuitive and does not require any interaction; hence observing the utilization of this product required an always on data collection strategy. On the other hand, the product in the case study has a defined interaction in discrete time intervals. The product in the second case study is utilized once in two days on average, therefore observing the use required longer data collection durations.

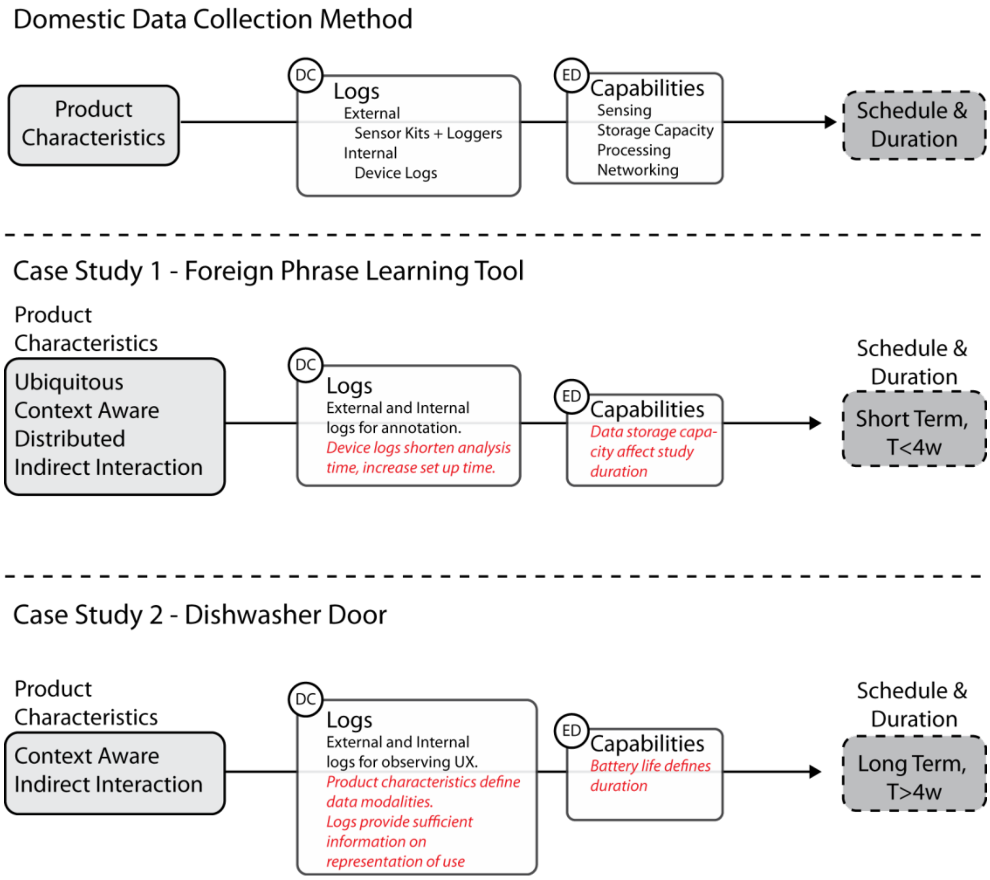


Figure 43 Implications of Product and Activity Characteristics on Study Duration and Schedule

Findings on the implications of product and activity characteristics on study duration might be summarized as follows;

- The frequency of interaction with products defines data collection duration.
- Interaction modality of product, whether it is explicit or implicit have influence on duration.
- Data logging capabilities of products influence their capabilities as a data source, and might decrease the observation and evaluation durations.

5.5.6. *Implications of Product and Activity Characteristics on Costs*

Proposed method predicts that product and activity characteristics influence costs of domestic data collection in terms of data collection method, equipment design, management and logistics (Figure 44). The findings of case studies demonstrated that utilizing data logging decreases the need for the utilization of external data collection equipment. If the product itself has data collection capabilities, it is cost effective to utilize these capabilities (study 2) otherwise utilizing external sensors and customized equipment is expensive in terms of financial costs (study1).

Especially for studies with large sample sizes, logistics have substantial financial costs; by designing robust maintenance-free data collection equipment, logistics costs can be decreased profoundly. Data collection equipment design should decrease the number and durations of field visits and the presence of researchers at participants' houses.

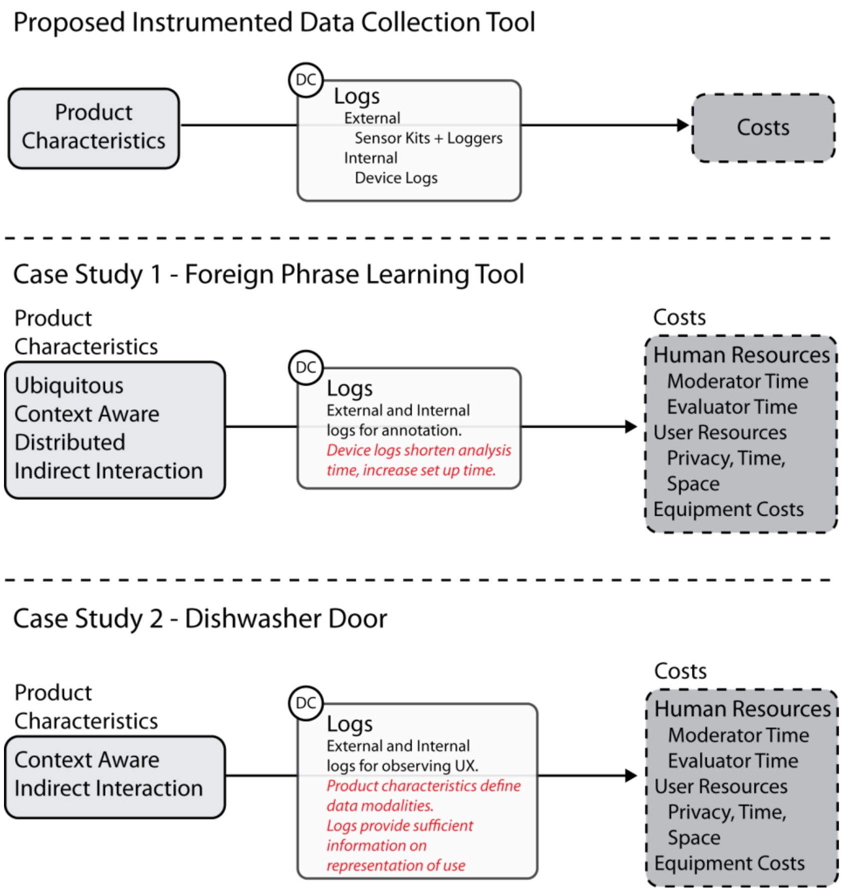


Figure 44 Implications of Product and Activity Characteristics on Costs

Early prototypes might have functionality problems and might generate errors more frequently during evaluations. This may cause disruptions in participants' daily routine, these malfunctions can be anticipated and their costs to user should be eliminated.

Defining the activities and setting up the data collection procedure is essential in terms of effective data collection. For example, in the second case study, participants' mental model of slightly opened door and researchers slightly opened door are different from each other, hence data collection equipment failed to capture some parts of interaction data.

The findings of case studies in terms of product and activity characteristics on costs might be summarized as follows;

- Products with internal data collection capabilities might decrease the costs associated with equipment design.
- Products that are distributed in the environment increases costs associated with data collection equipment design and costs associated with the participant.
- Robust maintenance free data collection equipment together with data collection capabilities of smart products might decrease the costs substantially.
- Clear definition of activities among the participants and researchers might decrease equipment set up and customization efforts.

5.5.7. Implications of Target Context Characteristics on Study Duration and Schedule

Although both studies were conducted in domestic environments, each and every participant's house is different. With keeping this in mind proposed method anticipated that equipment design and its capabilities, preparation before implementation and logistics might be the key points with which characteristics of target context have effects on schedule and duration of a data collection study (Figure 45).

Findings of the first case study demonstrated that collecting data on complete everyday life of users might shorten user research studies as product or activity can be observed for longer durations in a day. If equipment design permits, data collection can continue until the researcher's preference to end data collection; however, design decisions such as utilization of battery and data storage capacity limit study duration.

Physical and social factors both have implications on study duration since some contexts might not be welcoming as others. Therefore, privacy concerns of participants or visitors to data collection environment might limit data collection. Also the presence of pets or children might have effects on data collection equipment, or excess noise, heat and vibration might cause data loss and prolonged durations of data collection. Preparing data collection equipment against these contextual factors might decrease the risk of data loss and provide a more effective data collection procedure.

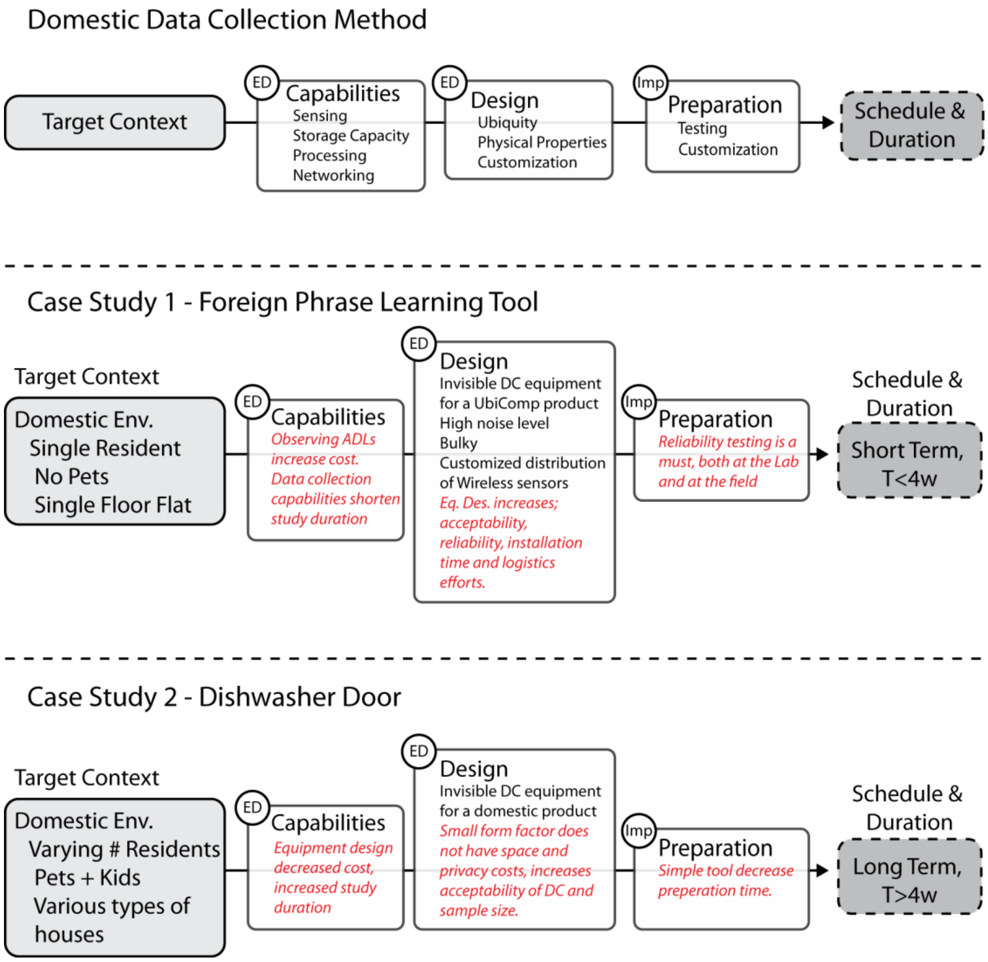


Figure 45 Implications of Target Context Characteristics on Study Duration and Schedule

Implications of use context on study duration can be summarized as follows;

- Physical context might hinder data collection in terms of noise, vibrations, illumination levels and temperature.
- Social context, in terms of children, pets and visitors might hinder data collection due to misplaced equipment and privacy.

- Equipment design might decrease the duration of pilot testing, installation and removal durations and might increase actual data collection process.
- Equipment capabilities to fit in context and maintenance free operation might increase study duration.

5.5.8. Implications of Target Context Characteristics on Cost

Proposed method assumes that target context influences costs associated with the user research study in terms of equipment design, capabilities of equipment, observation method and equipment management.

The results of case studies are generally in line with the proposed method. Only the logistics comes from second case study as another identifier of target contexts' influence on costs which is due to increased number of field visits in second case study (Figure 46).

Both of the studies employed data logging for annotating and observing the interaction data, although logs were effective to some degree, they were not fully utilized due to contextual factors. In the first case study false positives are very high for sensor readings because of the ambient vibrations in the building and products that emit strong vibrations such as trash dispenser.

The results of two case studies also demonstrated that failure in monitoring data collection equipment results in data loss. In the first case study one of the cameras and some sensors were failed and left unnoticed, consequently caused data loss. Similarly in the second study short battery lives cost data loss, as they haven't been noticed on time.

Implications of social context are also observed during the case studies. For example, in the first study participant mentioned his friend's visit and opinions on the data collection study; however, his friend was not visible in the video recordings, the participant shut down data collection at his friend's visit by unplugging the equipment. This might be due to his friend's privacy concerns. Another example comes from the second case study as three of the participants declined documentation of their kitchen environment. Moreover, in the second case study, 3 of the external data loggers were broken at the sites with children and pets.

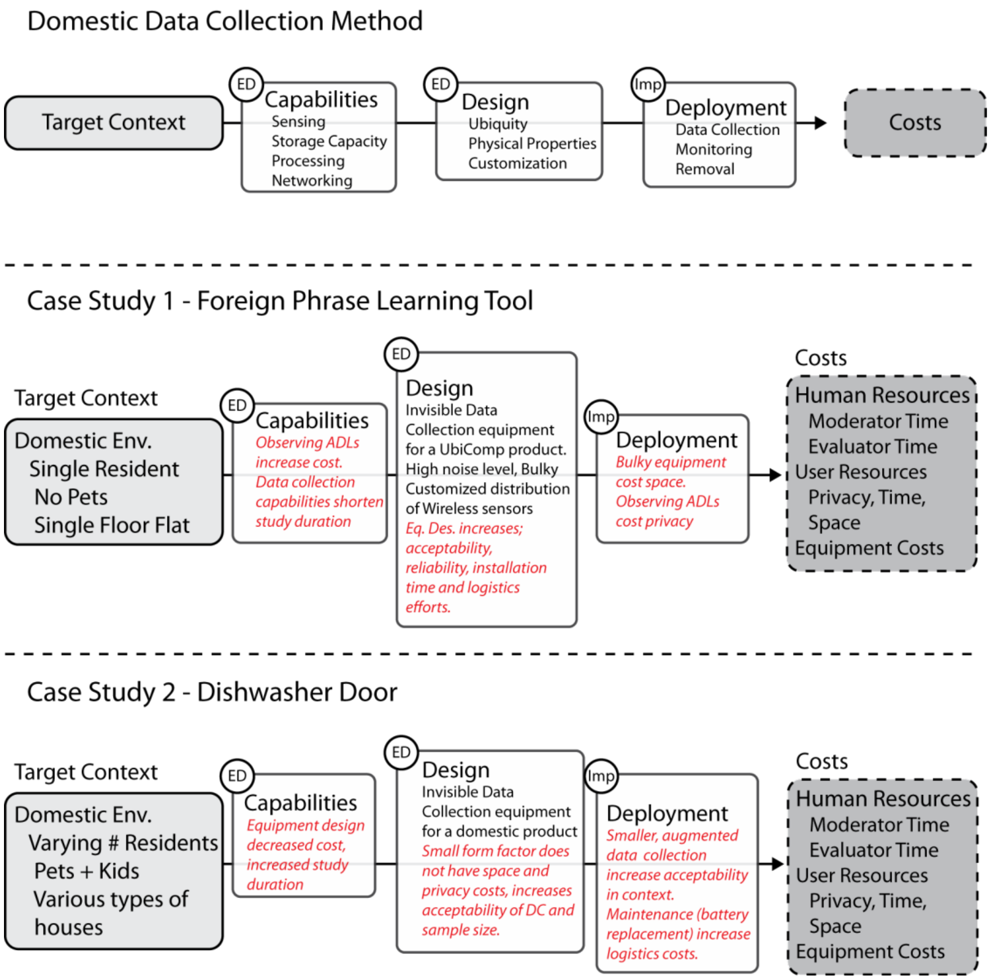


Figure 46 Implications of Target Context Characteristics on Cost

Implications of target use context on costs can be summarized as follows;

- Domestic environments are private and decorated based on residents' preferences. Implementing data collection equipment and observing house residents have privacy and spatial costs to the residents.
- Data collection equipment should be invisible at best, embedded and unnoticeable at worst. Any change in the environment is noticed by curious eyes of kids and pets; hence, equipment might be misplaced or broken.
- Equipment design might minimize the visibility of data collection tools and increase the acceptability of data collection in domestic environments.
- In order to minimize maintenance costs, data collection equipment should use infrastructure and it should not rely on battery power for long durations.

5.6. Discussion

Current study explores data collection procedures for the design and development of smart products in domestic environments, therefore user research studies and data collection procedures for these studies coincide in various sections of this manuscript. However, this study mainly focuses on data collection methods, equipment and procedures. Hence, user experience performance of the products under study, FPLT for the first case study and dishwasher door for the second case study, have secondary links to this study. Therefore, discussion will be based on the planning and procedure of domestic data collection method.

Findings of the study in general suggest that versatility of data collection methods, complexity of equipment design and customized implementation of data collection procedure have effects on the sample size, duration and costs of data collection studies. The interplay between the variables of user research studies and components of domestic data collection will be discussed in the following sections.

5.6.1. Discussion on Data Collection Methods

Both of the case studies utilized technological tools to support ethnographic methods for data collection. These methods include direct observation of participants as well as representation of use with sensor readings.

Grudin (2000) states that digital representation of context might miss some contextual factors which digital devices cannot capture but we as humans can capture and process. In line with this perspective multi-modal data collection including in context interviews were utilized in both of the case studies; however, direct observations with the presence of researchers were not conducted in any of the case studies.

Avoiding the presence of human observers in context has two major implications. Firstly, everyday activities, daily routine of the participant and the natural context are left as they and the natural set up is left uninfluenced while observation. Secondly, the interaction data is captured via data collection equipment and this equipment eventually filters the data based on the capabilities of the equipment and the skills of the researcher on utilizing the equipment.

As the focus of the first case study was a distributed ubiquitous product that did not require direct user interaction, the first study covered a complete domestic environment with a standalone data collection kit. Although data collection methods failed to capture ambient interactions, the triangulation of methods such as evaluating sensor readings in combination with audio/video recordings helped to elucidate uncertain situations. Similarly, the evaluation of audio/video recordings would be much more burdensome (Ylirisku & Buur, 2007) without the presence of automatically generated sensor logs. Sensor logs highlighted the activities in video stream and reduced the analysis time for video data (see Appendix B).

The second case study focused on a single activity introduced with a smart functionality of a domestic device. Therefore, data collection methods have a limited scope. Data collection methods set up to capture observations of this single activity and functionality. Similar to first case study, presence of researchers for the direct observation of activities is avoided; therefore the evaluation data is filtered either by the equipment or by the participant. In the first case study, sensor data is triangulated with the video data, in the second case study sensor data is triangulated with the device logs. However, transmission of device logs is problematic and triangulation is not achieved effectively in the second case study. Consequently, evaluations are based on the sensor reports based on the data from a simple sensor.

Over reliance on sensor readings for the data collection raised another issue on the results of sensor readings and participants' representation of the situation. Control group in the first case study named 2° opening of dishwasher door as slightly opened or ajar; however sensors record 10° opening as slightly opened or ajar. This misinterpretation created discrepancies between sensor logs and user reports.

To sum up, findings of the study in terms of data collection method demonstrated that;

- Triangulation of user data is a must for studies conducted in domestic environments without the presence of human observers.
- Redundancy of data sources and data collection equipment is essential for backup and reliability purposes.
- Users' self representation of usage must be collected and compared against other data sources.

- All the data sources must be synchronized and combined on a single timeline to digitally represent context as realistic as possible.

5.6.2. Discussion on Equipment Design

Custom designed data collection equipments are utilized for both of the case studies. The first case study utilized a high end, state of the art data collection equipment with an advanced software tool to annotate activities, whereas the second case study utilized a simple data logger and sensor couple.

BoxLab the primary means for data collection for the first case study aimed to instrument any given domestic environment and convert it into a live-in laboratory. Consequently, it requires a longer setup and customization time. The performance evaluation of BoxLab demonstrated that it worked robustly as a standalone data collection kit to capture everyday activities without the presence of a researcher in context. The initial costs associated with BoxLab might be relatively high; however, these costs are only a small fraction of building a live-in laboratory and maintaining it. BoxLab equipment is open-source and easy to duplicate. It is composed of off the shelf products and easy to upgrade.

The properties of current BoxLab design has issues related to the physical characteristics such as size, weight and noise levels; they all can be improved with a design iteration with the lessons learned from its first deployment. The physical size can be reduced by the utilization of a smaller form factor computer, which will help the weight and noise issues. With another iteration of the hardware the costs might be as low as a high end desktop personal computer. Therefore, BoxLab might be an affordable and accessible solution for domestic data collection needs of user researchers.

The data collection equipments in the second case study are custom made; one of them is the propriety of the manufacturer specifically designed for transmitting device logs to the research and development facilities at the production plant, the other is based on an open source system layout downloaded from Internet (Monat, 2011). The first one is a basic data transmitter which receives locally stored data from the dishwasher and transmits it to an FTP server; the second one is a basic sensor-logger couple which has a sensing input, a processor and small data storage. Its sensing capabilities are customized according to the requirements of data collection study.

The idea behind the data collection equipment utilized in the second case study is to couple internal data logs with an external sensor to observe interactions with the product. However, the lack of in context pilot testing resulted in issues related to real time data transmission from the contextual environments. Out of 19 device-log transmitters only 6 of them functioned properly and 13 of them never communicated with the server. As the equipment hardwired into the products, it was unfeasible to repair them during the study.

The external sensor is designed to collect data for a maximum of 10 days as the user research study requires weekly field visits to participants; however battery power issues limited the data collection capabilities of the sensor-logger couple. Aside from the power issues dishwasher door sensor performed well in capturing the target activity, which is set as capturing the opened, closed and slightly opened states of the dishwasher door. The slightly opened state is defined as 10º opening of the door by the researchers. However, it is observed that participants define slightly opened state as 2° opening of the door. Therefore, the gap between researchers and participants representation of the state of the door caused discrepancies in the data. Again these discrepancies might be because of the lack of in context pilot studies.

Findings of the both case studies suggest that data collection equipment must be tested for reliability and robustness both in context and in the laboratory. The external resources for the smooth operation of data collection equipment such as GPS, cellular network, internet and remote servers must be tested thoroughly. Data collection equipment components must be tested individually and together at least for one complete day of data. Data collection equipment must be invisible to the inhabitants of the environment, including the pets and children which are curious about newly added objects in the environment.

Lastly, but most importantly, data collection equipment must utilize external resources from available infrastructures where possible. For example, reliance on battery power should be minimized and devices should be connected to wall outlets for reliable data collection. Another example is the utilization of Wi-Fi networks instead of cellular GPRS networks, as quality of service for cellular internet connection shows variations over time.

To sum up, findings of the study in terms of equipment design demonstrated that;

- Data collection equipment must be invisible to the house residents, otherwise physical properties of data collection equipment (size, shape, noise, vibrations) should blend in the environment
- Data collection equipment needs to be portable and modular to meet the customization requirements of different house environments.
- Data collection equipment should permit remote monitoring and maintenance where possible.
- Data collection equipment must permit time synchronization among each other.
- Target activities should be defined in detail with respect to users' perception of the activity and data collection equipment should be customized accordingly.
- Data collection equipment should utilize resources from available infrastructure where possible.

5.6.3. Discussion on Implementation

Empirical study demonstrated that implementation of data collection procedure is a function of sample size and equipment design. The first case study has a single participant with a complex equipment design whereas the second case study has 29 participants with a simple equipment design.

One of the major advantages of domestic data collection method is the absence of a researcher in the context; however in order to justify the absence of the researcher, data collection tools must be capable of collecting the necessary data robustly and reliably. Customizing the data collection procedure through implementation in target context aims to achieve a flawless operation of equipment for a given sample size.

The findings of case studies demonstrated that a field visit to target context prior to data collection is necessary for the assessment of site for the customization and pilot testing of the equipment. In the first case study pilot testing is conducted for one day, however in case study two pilot testing is only conducted in laboratory and in context pilot testing is skipped due to large number of participants. Omitting pilot test resulted in data loss that most of the data transmitters do not function properly.

Another key finding of the case studies is the necessity to monitor data collection equipment synchronously for possible failures of the equipment. BoxLab in the first case study has the means for reporting its state and remote access to its certain features such as power management and system restart options. However, data collection equipment in the second case study does not report its state and cause data loss because of drained batteries. Short battery life increased the frequency of field visits, consequently logistics costs are increased. Four field visits per participant in the second case study consumed substantial amount of researcher and participant time.

Except two minor issues regarding the documentation of contextual environments in case study two, there is no privacy issues raised regarding the data collection in both of the case studies. The first study stored data locally at participant's house, whereas the second study removed data from participants' environment on a regular basis. Although the sensitivities of the collected data in the case studies are different, the privacy management approach, giving full control to the participants over their private data worked flawlessly.

Findings of the study in terms of implementation can be summarized as follows;

- Data collection procedure should present minimum burden to the house residents.
- Conducting at least two field visits is essential for the implementation of data collection, however a third visit before actual data collection for assessing the pilot data collection is necessary.
- Equipment should be tested thoroughly in context and should be monitored during data collection
- For studies with large sample sizes data collection equipment should work standalone and minimize field visits.
- Participants should have the full control over data collection, they should be able to pause data collection.

5.6.4. Revised Method

Domestic data collection method presented in section 4.2 is revised based on the findings of two case studies. Findings suggests that independent variables of research studies; study type (formative, summative), product characteristics (degree of smartness) and target use context (social and physical characteristics of domestic environment), have effects on the sample size, duration and costs associated to the study. Additionally, it was found that dependent variables of data collection; sample size, study duration and costs associated with the study have a reciprocating interaction with triangulation of data collection methods, complexity of equipment design and customized implementation of data collection procedure.

The observed links between independent and dependent variables of the study is presented in Figure 47. Links between independent variables of the study are out of the scope of the study; hence they are omitted in Figure 47. On the other hand, it was observed that dependent variables of a user research study have effects on each other and affected by independent variables, therefore sample size, duration and costs of a user research study is a tradeoff among these variables.

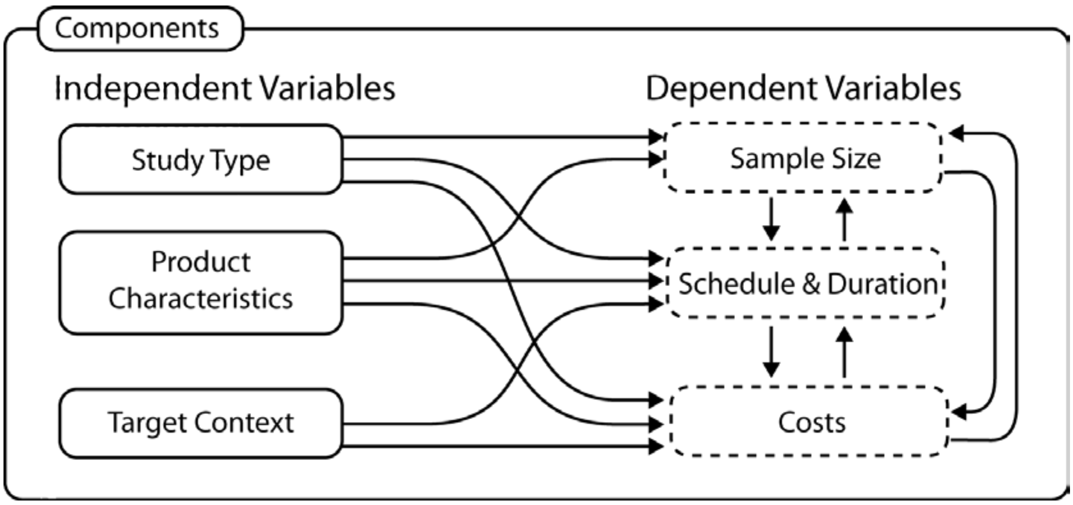


Figure 47 The links between dependent and independent variables

The type of the study whether formative or summative and smart product characteristics have effects on all three of the dependent variables whereas target context which selected as domestic environments for the current study has effects on costs and duration of the study. Sample size can be any number independent of target context as the study procedure can be replicated as many times as required with sufficient resources.

Based on the findings of the case studies overall method outline (see Figure 7) is revised and presented in Figure 48. The findings demonstrated that pilot testing both at the laboratory and in context are crucial for standalone data collection tools. Moreover, customizing the equipment based on a detailed assessment of each data collection site and participant is essential for deployment of data collection procedures.

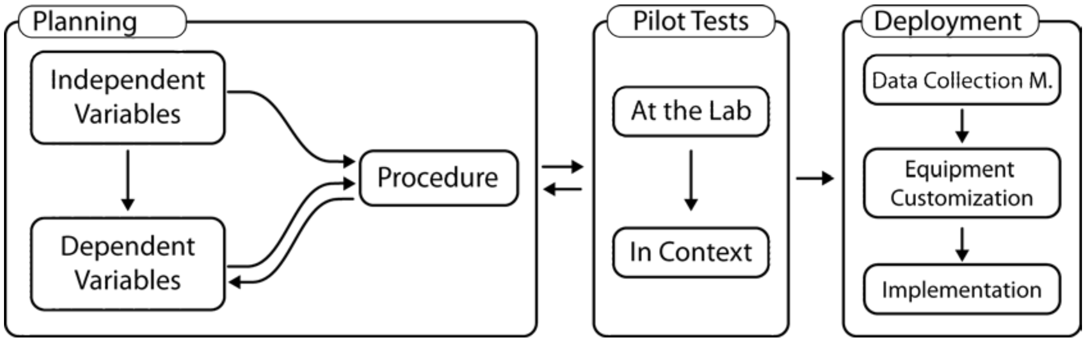


Figure 48 Domestic Data Collection Method Outline

In the light of reviewed literature and the findings of the empirical studies domestic data collection method demonstrated in Figure 6 is revised and updated (Figure 49). In general, the findings of the case studies demonstrated that, in the absence of a human observer data collection can be achieved with technological tools in domestic environments. However, redundancy of data collection methods, capturing subjective user representations of interactions and standalone robust data collection equipment are essential for an effective user research procedure.

For user research studies that fall in the scope of the domestic data collection method; planning and deployment are identified as the two major phases. The planning phase defines study components and procedure, whereas deployment phase identifies logistics, equipment customization and monitoring. Between planning and deployment phases data collection equipment and procedure must be tested with pilot tests conducted both at the laboratory and at participant’s own environment.

As the method assumes all the physical interaction with the equipment at researcher side will cease at the beginning of data collection and the equipment will operate standalone, the deployment phase is divided by the start and end of data collection study. During actual data collection process remote monitoring of the equipment and data is necessary for early detection of flaws in the procedure.

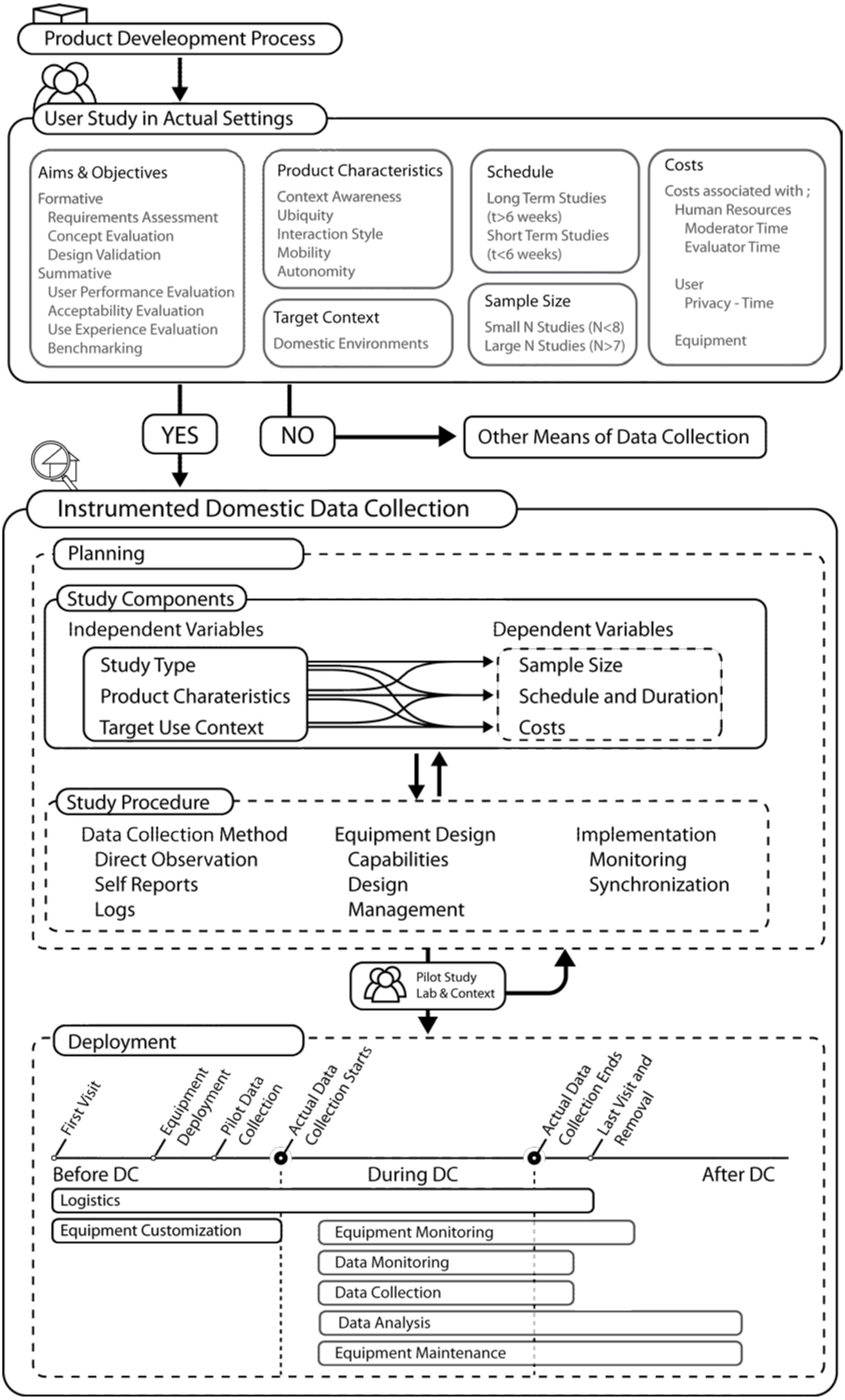


Figure 49 Revised Domestic Data Collection Tool Outline

CHAPTER 6

CONCLUSION

Current study identified the components of data collection in domestic environments for supporting user research studies that focus on smart products. It is found that capabilities of smart products, socio-physical and private nature of domestic environments and the requirements of user research studies are the major components which can support data collection procedures.

Computational capabilities of smart products are increasing continuously and interaction modalities are transforming from explicit to implicit, ambient interactions. Hence, evaluating these implicit interactions require data collection on the product actions, user activities and the environmental factors. Interactions with smart products that do not require an interface as in the FPLT example demonstrates that observing these interactions require both device and user perspectives in data collection. Therefore, device logs, user self reports and contextual factors should be captured and evaluated synchronously.

Data collection on the mundane repetitive activities of everyday life as in the dishwasher study example might provide information on the needs, expectations and perceptions of users. Hence, might lead to a user driven instead of technology driven design process.

Observing domestic environments with technological instruments provided the opportunity to collect data on mundane everyday activities. Populating data sets similar to case study one, setting standardized activity definitions and sharing annotated data sets might lead to a large sample of population for domestic activities. Moreover, millions of devices with sensors and web connectivity collect aggregated user data. Therefore, data will be readily available for any activity for researchers, without the hassle of data collection.

Although, utilization of technological instruments promises such opportunities, the biggest challenge for them is to invisibly deploy them without altering the domestic environment and transforming the activity under observation. Moreover, data collection equipment must be adaptable to socio-physical variations at domestic environments and robust to and safe for the curious residents, such as kids and pets.

6.1. *Summary of Findings*

The study demonstrated that customized digital data collection tools can support user research studies without the presence of a researcher in domestic environments. Additionally, standalone low cost data collection instruments enable simultaneous data collection studies in multiple sites, consequently increase number of study participants and observation duration in a cost effective manner.

On the contrary, findings of empirical research presented that over reliance on single data collection equipment or source has the risks of overlooking and losing user and contextual data, hence triangulation of methods and redundancy of data sources and data collection equipment is necessary for a secure, robust and reliable data collection procedure. Moreover, data collection with a variety of tools and methods creates a more elaborate representation of context and user activities.

The study presents findings on data collection equipment design, customization and implementation, which might be listed as follows;

- Data collection equipment must be invisible to the residents and activities.
- Utilization of multiple data collection tools or methods is necessary for the digital representation of the environment and triangulation of data.
- Participants should have full control over the data and data collection.
- Utilizing device logs for capturing interface events supports user studies.
- Besides the two field visits a third visit for pilot data collection is necessary.
- For studies with large sample sizes logistics is a major cost in terms of both researcher time and financial costs.
- Standalone operation of equipment requires a continuous connectivity to technological infrastructure such as power and network.
- Equipment for direct observation require maintenance and management during data collection.

- Customization of data collection equipment for target use contexts is necessary
- Equipment must be portable and easy to setup, customize and remove.

6.2. Benefits and Contributions

The proposed method can be utilized for further data collection studies in domestic environments. It supports researchers in terms of planning and deployment of data collection studies in domestic environments.

For the first case study a portable open source sensor kit (BoxLab) is designed in collaboration with House_n Research Group at MIT (Cambridge, MA), which can convert study participants' own houses into a live-in laboratory for user research purposes. BoxLab is an open source project and anyone can build a similar data collection equipment for research purposes with the online guidelines (House_n, 2009). The second case study utilized another open source tool (Monat, 2011) *Skylar 2* to build the sensor and data logger couple, which is built and customized in UTEST product usability unit to meet the requirements of user research study. Utilization of open source tools increases the cost effectiveness of equipment design and customization of data collection equipment. This study provides a novel approach for data collection equipment design by combining open source equipment and requirements of custom data collection procedures.

The study demonstrated limitations and benefits of various data collection methods and identified that redundancy of data collection tools and methods are necessary for a reliable data collection procedure.

6.3. Limitations of the Study

The data collection tools that are utilized in empirical study are both prototypes and utilized for the first time in naturalistic contexts with the current study. Prototypical nature of the tools raised reliability and robustness issues as well as functionality problems in some cases. At particular points these functionality problems caused data loss.

Number of participants and data collection duration might be increased to collect a more profound account of a ubiquitous distributed data collection. Although, observatory and experimental data is collected with one participant and 5 days of data collection, utilization of BoxLab for multiple sites, participants and longer durations cannot be achieved during the time span of the study.

Sensor kits and internal device logs are heavily utilized in both of the case studies. Although digitally captured data minimized burden to the users, field visits and researchers' presence at the study site, subjective representations of users' needs, expectations and anticipations of use are overlooked as a tradeoff.

6.4. Suggestions for Further Studies

This study provided a method for compiling a customized data collection study and presented two data collection equipments. These tools are fully customizable to the requirements of particular user research studies. Further studies can utilize these tools and might create data sets that are in a standard format, which enables the researcher to increase sample sizes for a given population and understand their everyday activities.

Both of the case studies are focused on creating minimal distraction to the participants during the data collection period. Therefore, data collection is heavily relied on external data collection equipment and internal device logs and overlooked participant self reports as a tradeoff. Although the first case study was manageable in terms of user self reports, the meaning layer of user experience (see Figure 4) which is shaped by social cultural norms and participants' background and anticipated future cannot be captured in the second case study. Further studies can formulate data collection tools that aim to collect data for the meaning layer of user experiences. In addition to these further studies might focus on the design and development of data collection equipment that reports subjective data with minimum burden during the study duration.

REFERENCES

Aarts, E., & Eggen, B. (Eds.). (2002). *Ambient Intelligence in HomeLab*. Eindhoven, The Netherlands: Neroc.

Abowd, G. D. (1999). "Classroom 2000: An Experiment with the Instrumentation of a Living Educational Environment. *IBM Systems Journal, 38*(4), 508-530.

Abowd, G. D., & Mynatt, E. D. (2000). Charting Past, Present, and Future Research in Ubiquitous Computing. *ACM Transactions on Computer-Human Interaction, 7*(1), 29-58.

Ackerman, M., Darrell, T., & Weitzner, D. J. (2001). Privacy in Context. *Human-Computer Interaction, 16*, 167-176.

Aitenbichler, E., Lyardet, F., Austaller, G., Kangasharju, J., & Muhlhauser, M. (2007). *Engineering intuitive and self-explanatory smart products*. Paper presented at the Proceedings of the 2007 ACM symposium on Applied computing.

Alben, L. (1996). Quality of experience: defining the criteria for effective interaction design. *Interactions, 3*(3), 11-15.

Ambient Umbrella. (2008, December 14) *Ambient Devices*. retrieved from http://www.ambientdevices.com/products/umbrella.html

André, P., Schraefel, M. C., Dix, A., & White, R. W. (2011). *Expressing well-being online: towards self-reflection and social awareness*. Paper presented at the Proceedings of the 2011 iConference.

Ball, A. D., & Tasaki, L. H. (1992). The Role and Measurement of Attachment in Consumer Behavior. *Journal of Consumer Psychology, 1*(2), 155-172.

Ballard, B. (2007). *Designing the Mobile User Experience*: John Wiley \& Sons.

Battarbee, K. (2003). *Defining co-experience*. Paper presented at the Proceedings of the 2003 international conference on Designing pleasurable products and interfaces.

Battarbee, K., Koskinen, I., Hendrik, N. J. S., & Paul, H. (2008). Co-experience: Product experience as social interaction *Product Experience* (pp. 461-476). San Diego: Elsevier.

Beaudin, J., Intille, S., & Tapia, E. M. (2004). *Lessons Learned Using Ubiquitous Sensors for Data Collection in Real Homes.* Paper presented at the Proceedings of CHI 2004, Vienna, Austria.

Bell, G., Blythe, M., Gaver, B., Sengers, P., & Wright, P. (2003). *Designing Culturally Situated Technologies for the Home.* Paper presented at the Proceedings of CHI 2003, Ft. Lauderdale FL.

Bellotti, V., & Edwards, K. (2001). Intelligibility and Accountability: Human Considerations in Context-Aware Systems. *Human-Computer Interaction, 16*, 193-212.

Blythe, M., Park, J., & Monk, A. (2004). *Tele-Biographies: Data Collection Techniques to Capture the Ways People Interact with Digital TV.* Paper presented at the Proceedings of CHI 2004, Vienna, Austria.

Bowers, J., Bannon, L., Fraser, M., Hindmarsh, J., Benford, S., Heath, C., et al. (2007). From the Disappearing Computer to Living Exhibitions: Shaping Interactivity in Museum Settings *The Disappearing Computer* (pp. 30-49).

Bowman, D. A., Gabbard, J. L., & Hix, D. (2002). A Survey of Usability Evaluation in Virtual Environments: Classification and Comparison of Methods. *Presence: Teleoperators & Virtual Environments, 11*(4), 404-424.

Brown, B. A. T., Sellen, A. J., & O'Hara, K. P. (2000). *A diary study of information capture in working life*. Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems.

Brown, P. J., Bovey, J. D., & Chen, X. (1997). Context-aware applications: From the laboratory to the marketplace. *IEEE Personal Communications, 5*(4), 58-64.

Castillo, J. C., Hartson, H. R., & Hix, D. (1998). *Remote usability evaluation: can users report their own critical incidents?* Paper presented at the CHI 98 conference summary on Human factors in computing systems.

Chamorro-Koc, M., Popovic, V., & Emmison, M. (2008). Using visual representation of concepts to explore users and designers' concepts of everyday products. *Design Studies, 29*(2), 142-159.

Charlton, S. G., & O'Brien, T. G. (Eds.). (2002). *Handbook of Human Factors Testing and Evaluation*. New Jersey: Lawrence Erlbaum Associetes, Publishers.

Consolvo, S., Arnstein, L., & Franza, R. B. (2002). *User Study Techniques in the Design and Evaluation of a Ubicomp Environment.* Paper presented at the Proceedings of Ubicomp 2002: Ubiquitous Computing, Goteborg, Sweden.

Cook, D., & Das, S. (2004). *Smart Environments: Technology, Protocols and Applications (Wiley Series on Parallel and Distributed Computing)*: Wiley-Interscience.

Cranor, L., Langheinrich, M., Marchiori, M., & Reagle, J. (2002). The Platform for Privacy Preferences. *W3C - World Web consortium*. Retrieved from http://www.w3.org/TR/2002/REC-P3P-20020416/

Dey, A. K. (1998). *Context-Aware Computing: The CyberDesk project.* Paper presented at the Proceedins of the AAAI'98 Spring Symposium on Intelligent Environments, Menlo Park, CA.

Dey, A. K., Abowd, G. D., & Salber, D. (2001). A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications. *Human-Computer Interaction, 16*, 97-166.

Dhebar, A. (1996). Information technology and product policy: [`]Smart' products. *European Management Journal, 14*(5), 477-485.

Dourish, P. (2006). *Implications for design*. Paper presented at the Proceedings of the SIGCHI conference on Human Factors in computing systems.

Endsley, M. r., Bolté, B., & Jones, D. G. (2003). *Designing for Situation Awareness*. London: Taylor and Francis.

Fishkin, K. P. (2004). A Taxonomy for and Analysis of Tangible Interfaces. *Personal and Ubiquitous Computing, 8*, 347-358.

Folmer, E., & Bosch, J. (2004). Architecting for usability: a survey. *Journal of Systems and Software, 70*(1-2), 61-78.

Forlizzi, J. (2007). The Product Ecology: Understanding Social Product Use and Supporting Design Culture. *International Journal of Design, 2*(1), 11-20.

Forlizzi, J., & Battarbee, K. (2004). *Understanding Experience in Interactive Systems.* Paper presented at the Proceedings of DIS2004, Cambridge, MA.

Forlizzi, J., & Ford, S. (2000). *The building blocks of experience: an early framework for interaction designers*. Paper presented at the Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques.

Frohlich, D., & Kraut, R. (2003). The Social Context of Home Computing. In R. Harper (Ed.), *Inside the Smart Home* (pp. 127-162): Springer London.

Gaver, B., Dunne, T., & Pacenti, E. (1999). Design Cultural Probes. *Interactions*, 21-29.

Greenberg, S. (2001). Context as a dynamic construct. *Human-Computer Interaction, 16*(2-4), 257-268.

Greenwald, A. G. (1988). A Social-cognitive account of the self's development. . In D. K. Lapsley & F. C. Power (Eds.), *Self, ego, and identity: Integrative approaches* (pp. 30-42). New York: Springer-Verlag.

Grudin, B. N., Plotnikov, V. S., & Fishchenko, V. K. (2000). Investigation of correlation-spectral characteristics of long-wavelength inhomogeneities in amorphous metallic materials using electron-optical images. *Physics of Metals and Metallography, 90*(5), 434-438.

Grudin, J. (2001). Desituating action: Digital representation of context. *Human-Computer Interaction, 16*(2-4), 269-286.

Hammersley, M., & Atkinson, P. (1983). *Ethnography Principles and practice*. London, New York: Routledge.

Harper, R. (Ed.). (2003). *Inside the Smart Home*. London: Springer - Verlag.

Hassenzahl, M. (2004a). The Interplay of Beauty, Goodness, and Usability in Interactive Products. *Human-Computer Interaction, 19*(4), 319-349.

Hassenzahl, M. (2004b). The thing and I: understanding the relationship between user and product *Funology: from usability to enjoyment* (pp. 31-42): Kluwer Academic Publishers.

Hassenzahl, M. (2010). *Experience Design: Technology for All the Right Reasons (Synthesis Lectures on Human-Centered Informatics)*: Morgan and Claypool Publishers.

Hassenzahl, M., & Tractinsky, N. (2006). User experience: a research agenda. *Behaviour & Information Technology, 25*(2), 91 - 97.

Hayes, B. (2008). Cloud computing. *Communications of the ACM, 51*(7), 9-11.

Hertzum, M., & Jacobsen, N. E. (2001). The Evaluator Effect: A Chilling Fact about Usability Evaluation Methods. *International Journal of Human-Computer Interaction, 13*(4), 421-443.

Hilbert, D. M., & Redmiles, D. F. (2000). Extracting Usability Information from User Interface Events. *ACM Computing Surveys,, 32*(4), 384-421.

Hindus, D. (1999). *The Importance of Homes in Technology Research.* Paper presented at the Proceedings of Cooperative Buildings (CoBuild'99), Pitssburg, USA.

Hornecker, E. (2011). The role of physicality in tangible and embodied interactions. *Interactions, 18*(2), 19-23.

Hornecker, E., & Buur, J. (2006). *Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction.* Paper presented at the CHI 2006 Proceedings - Designing Tangible Interactions, Montreal, Quebec.

House_n. (2009). http://boxlab.wikispaces.com/. Retrieved 06.06.2011

Howard, S., Kjeldskov, J., & Skov, M. B. (2007). Pervasive Computing in the Domestic Space. *Personal and Ubiquitous Computing, 11*, 329-333.

Hulkko, S., Mattelmäki, T., Virtanen, K., & Keinonen, T. (2004). *Mobile Probes.* Paper presented at the Proceedings of the third Nordic conference on Human-computer interaction - NordiCHI`04, Tampere, Finland.

Hutchinson, H., Mackay, W., Westerlund, B., Bederson, B. B., Druin, A., Plaisant, C., et al. (2003). *Technology Probes: Inspiring Design for and with Families.* Paper presented at the Proceedings of CHI`03, Ft. Lauderdale, FL USA.

Intille, S., & Ho, J. (2005). *Using Context-Aware Computing to Reduce the Perceived Burden of Interruptions from Mobile Devices.* Paper presented at the CHI'05, Portland, Oregon, USA.

Intille, S., Rondoni, J., Kukla, C., Iacono, I., & Bao, L. (2003). *A Context Aware Experience Sampling Tool.* Paper presented at the Proceedings of CHI '03 Extended Abstracts on Human, New York NY.

Intille, S., Tapia, E. M., Rondoni, J., Beaudin, J., Kukla, C., Agarwal, S., et al. (2003). Tools for Studying Behavior and Technology in Natural Settings *UbiComp 2003: Ubiquitous Computing : 5th International Conference, Seattle* (pp. 157-174). Seattle WA: Springer-Verlag Berlin Heidelberg.

Intille, S. S., Larson, K., Beaudin, J. S., Nawyn, J., Tapia, E. M., & Kaushik, P. (2005). *A living laboratory for the design and evaluation of ubiquitous computing technologies.* Paper presented at the CHI '05 extended abstracts on Human factors in computing systems, Portland, OR. USA.

Intille, S. S., Larson, K., Tapia, E. M., Beaudin, J. S., Kaushik, P., Nawyn, J., et al. (2006). *Using a Live-in Laboratory for Ubiquitous Computing Research.* Paper presented at the 4th International Conference, PERVASIVE 2006, Dublin, Ireland.

Intille, S. S., Lee, V., & Pinhanez, C. (2003). *Ubiquitous Computing in the Living Room: Concept Sketches and an Implementation of a Persistent User Interface.* Paper presented at the Proceedings of UBICOMP 2003 Video Program, Seattle, WA.

Ishii, H. (2008). *Tangible Bits: Beyond Pixels.* Paper presented at the Proceedings of the second International Conference on Tangible and Embedded Interaction (TEI`08), Bonn, Germany.

Ishii, H., & Ullmer, B. (1997). *Tangible bits: towards seamless interfaces between people, bits and atoms.* Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems, Atlanta, Georgia USA.

ISO. (2002). ISO/IEC 9126-4: *Software engineering – software product quality – Part 4: Quality in Use Metrics,* International Standards Organisation.

Isomursu, M., Tahti, M., Vainamo, S., & Kuutti, K. (2007). Experimental evaluation of five methods for collecting emotions in field settings with mobile applications. *Int. J. Hum.-Comput. Stud., 65*(4), 404-418.

Jacob, R. J. K., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., et al. (2008). *Reality Based Interaction: A Framework for post-WIMP Interfaces.* Paper presented at the CHI 2008 Proceedings · Post-WIMP, Florence, Italy.

Jokela, T. (2004). When good things happen to bad products: where are the benefits of usability in the consumer appliance market? *Interactions, 11*(6), 28-35.

Kahn, J. M., Katz, R. H., & Pister, K. S. J. (1999). *Next century challenges: mobile networking for "Smart Dust"*. Paper presented at the Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking.

Kalof, L., Dan, A., & Dietz, T. (2008). *Essentials of Social Research*. New York: Open University Press.

Karapanos, E., Zimmerman, J., Forlizzi, J., & Martens, J.-B. (2009). *User experience over time: an initial framework*. Paper presented at the Proceedings of the 27th international conference on Human factors in computing systems.

Kern, N., Schiele, B., & Schmidt, A. (2007). Recognizing context for annotating a live life recording. *Personal and Ubiquitous Computing, 11*(4), 251-263.

Keyson, D. V., Hendrik, N. J. S., & Paul, H. (2008). The experience of intelligent products *Product Experience* (pp. 515-530). San Diego: Elsevier.

Kidd, C. D., Orr, R., Abowd, G. D., Atkeson, C. G., Essa, I. A., MacIntyre, B., et al. (1999). *The Aware Home: A Living Laboratory for Ubiquitous Computing Research.* Paper presented at the CoBuild'99 - Cooperative Buildings. Integrating Information, Organizations and Architecture, Pittsburgh, PA.

Kort, J., & Poot, H. d. (2005). *Usage Analysis: Combining Logging and Qualitative Methods.* Paper presented at the Proceedings of CHI 2005 Workshops, Portland Oregon.

Kuutti, K. (1995). Activity theory as a potential framework for human-computer interaction research *Context and consciousness: activity theory and human-computer interaction* (pp. 17-44): Massachusetts Institute of Technology.

Larson, R., & Csikszentmihalyi, M. (1983). The Experience Sampling Method. *New Directions for Methodology of Social & Behavioral Science, 15*(March 1983,), 41-56.

Law, E. L.-C., Roto, V., Hassenzahl, M., Vermeeren, A. P. O. S., & Kort, J. (2009). *Understanding, scoping and defining user experience: a survey approach*. Paper presented at the Proceedings of the 27th international conference on Human factors in computing systems.

Law, E. L.-C., Vermeeren, A. P. O. S., Hassenzahl, M., & Blythe, M. (2007). *Towards a UX manifesto*. Paper presented at the Proceedings of the 21st British HCI Group Annual Conference on HCI 2008: People and Computers XXI: HCI...but not as we know it - Volume 2.

Mackay, W. E. (1995). *Ethics, Lies and Videotape.* Paper presented at the Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'95), New York, NY.

Mankoff, J., Dey, A. K., Hsieh, G., Kientz, J., Lederer, S., & Ames, M. (2003). *Heuristic Evaluation of Ambient Displays.* Paper presented at the Proceedings of ACM-SIGCHI 2003, Lauderdale, FL.

Masten, D., & Plowman, T. M. P. (2003). Digital Ethnography: The next wave in understanding the consumer experience. *Design Management Journal, 14*(2), 75-81.

Mattelmäki, T. (2005). Applying probes – from inspirational notes to collaborative insights. *CoDesign, 1*(2), 83-102.

McCarthy, J., & Wright, P. (2004). *Technology as Experience*. Cambridge, MA: MIT Press.

Meyer, S., & Rakotonirainy, A. (2003). *A Survey of Research on Context Aware Homes.* Paper presented at the Conferences in Research and Practice in Information Technology, Adelaide.

Millen, D. R. (2000). *Rapid Ethnography: Time Deepening Strategies for HCI Field Research.* Paper presented at the Proceedings of DIS'00, Brooklyn, NY.

Monat, L. (2011). http://mondo-technology.com/spydar2.htm. *Mondo Technology* Retrieved May 10, 2010

Moore, G. (1965). Cramming More Components onto Integrated Circuits. *Electronics, 38*(8), 114-117.

Morris, M., Lundell, J., Dishman, E., & Needham, B. (2003). New Perspectives on Ubiquitous Computing from Ethnographic Study of Elders with Cognitive Decline *UbiComp 2003: Ubiquitous Computing* (pp. 227-242).

Mozer, M. (1998). *The neural network house: An environment that adapts to its inhabitants.* Paper presented at the Proceedings of the American Association for Artificial Intelligence Spring Symposium, Menlo Park, CA.

Nardi, B. A. (Ed.). (1995). *Context and consciousness: activity theory and human-computer interaction*: Massachusetts Institute of Technology.

Nguyen, D. H., Marcu, G., Hayes, G. R., Truong, K. N., Scott, J., Langheinrich, M., et al. (2009). *Encountering SenseCam: personal recording technologies in everyday life*. Paper presented at the Proceedings of the 11th international conference on Ubiquitous computing.

Palen, L., & Salzman, M. (2002). *Voice-mail diary studies for naturalistic data capture under mobile conditions*. Paper presented at the Proceedings of the 2002 ACM conference on Computer supported cooperative work.

Petersen, M. G., Madsen, K. H., & Kjaer, A. (2002). The usability of everyday technology: emerging and fading opportunities. *ACM Trans. Comput.-Hum. Interact., 9*(2), 74-105.

Philipose, M., Fishkin, K. P., Perkowitz, M., Patterson, D. J., Fox, D., Kautz, H., et al. (2004). Inferring Activities from Interactions with Objects. *Pervasive Computing*, 50-57.

Picard, R. W. (1999). *Affective Computing for HCI.* Paper presented at the Proceedings of HCI International (the 8th International Conference on Human-Computer Interaction) on Human-Computer Interaction: Ergonomics and User Interfaces-Volume I, Hillsdale, NJ USA.

Posland, S. (2009). *Ubiquitous Computing: Smart Devices, Environments and Interactions*. West Sussex: John Wiley & Sons Ltd.

Preece, J., Rogers, Y., & Sharp, H. (2001). *Beyond Interaction Design: Beyond Human-Computer Interaction*: John Wiley & Sons, Inc.

Reeves, B., & Nass, C. (1996). *The media equation: how people treat computers, television, and new media like real people and places*: Cambridge University Press.

Rijsdijk, S., Hultink, E., & Diamantopoulos, A. (2007). Product intelligence: its conceptualization, measurement and impact on consumer satisfaction. *Journal of the Academy of Marketing Science, 35*(3), 340-356.

Robertson, S., & Robertson, J. (2006). *Mastering the Requirements Process (2nd Edition)*: Addison-Wesley Professional.

Robinson, J. P., & Godbey, G. (1997). *Time for Life: The Surprising Ways the Americans Use Their Time*. Pennsylvania: Pennsylvania State University Press.

Rose, A., Shneiderman, B., & Plaisant, C. (1995). *An Applied Ethnographic Method for Redesigning User Interfaces.* Paper presented at the Proceedings of Symposium on Designing Interactive Systems, DIS'95, Ann Arbor MI USA.

Rubin, J., Chisnell, D., & Spool, J. (2008). *Handbook of Usability Testing: Howto Plan, Design, and Conduct Effective Tests*: Wiley.

Ruyter, B. D., & Aarts, E. (2004). *Ambient Intelligence.* Paper presented at the Proceedings of AVI 2004 Advanced Visual Interfaces International Working Conference, Gallipoli, Italy.

Ryan, N., Pascoe, J., & Morse, D. (1997). Enhanced Reality Framework: The Context Aware Archaeological Assistant *Computer Applications in Archeology*. Oxford, UK: Tempus Reparatum.

Schifferstein, H. N. J., & Hekkert, P. (2008). *Product Experience*. New York: Elsevier.

Schifferstein, H. N. J., & Zwartkruis-Pelgrim, E. P. H. (2008). Consumer-Product Attachment: Measurement and Design Implications. *International Journal of Design [Online], 2*(3), Available: http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/325/218

Schilit, B., & Theimer, M. (1994). Disseminating active map information to mobile hosts. *IEEE Network*, 22-32.

Scholtz, J., & Consolvo, S. (2004) Towards a discipline for evaluating ubiquitous computing applications. Intel Research Technical Report IRS-TR-04-004.

Siegel, D., & Dray, S. (2005). Avoiding the next Schism: Ethnography and Usability. *Interactions*, 58-61.

Silverman, D. (2010, June 24, 2010). Are You Seeing these IPhone Issues? *Houston Chronicle*.

Simonsen, J., & Kensing, F. (1997). Using ethnography in contextural design. *Commun. ACM, 40*(7), 82-88.

Soppera, A., & Burbridge, T. (2004). Maintaining Privacy in Pervasive Computing — Enabling Acceptance of Sensor-Based Services. *BT Technology Journal, 22*(3), 106-118.

Squicciarini, A. C., Shehab, M., & Paci, F. (2009). *Collective privacy management in social networks*. Paper presented at the Proceedings of the 18th international conference on World wide web.

Strauss, A., & Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Newbury Park, CA: Sage Publications.

Streitz, N., Kameas, A., & Mavrommati, I. (2007). *The Disappearing Computer* (Vol. 4500): Springer.

Swallow, D., Blythe, M., & Wright, P. (2005). *Grounding experience: relating theory and method to evaluate the user experience of smartphones*. Paper presented at the Proceedings of the 2005 annual conference on European association of cognitive ergonomics.

Tapia, E. M., Intille, S. S., Lopez, L., & Larson, K. (2006). *The Design of a Portable Kit of Wireless Sensors for Naturalistic Data Collection.* Paper presented at the Proceedings of PERVASIVE 2006, Dublin, Ireland.

Taylor, A. S., Harper, R., Swan, L., Izadi, S., Sellen, A., & Perry, M. (2007). Homes That Make Us Smart. *Personal and Ubiquitous Computing*, 383-393.

Tullis, T., & Albert, B. (2008). *Measuring the User Experience* Morgan Kaufman.

Underkoffler, J., & Ishii, H. (1999). *Urp: A Luminious Tangible Workbench for Urban Planning and Design.* Paper presented at the Proceedings of CHI 1999.

US Federal Trade Commission. (2000). *Fair Information Practice Guidelines. Privacy Online: Fair information practices in the electronic marketplace.* Retrieved from http://www.ftc.gov/reports/privacy2000/privacy2000.pdf.

Van Dam, A. (1997). Post-WIMP user interfaces. *Communications of the ACM, 40*(2), 278-285.

Venkatesh, A., Stolzoff, N., Shih, E., & Mazumdar, S. (2001). The Home of the Future: An Ethnographic Study of New Information Technologies in the Home. [Article]. *Advances in Consumer Research, 28*(1), 88-97.

Weiser, M. (1991). The Computer for the 21st Century. *Scientific American, 265*(3), 94-104.

Weiser, M. (1993). Some Computer Science Issues in Ubiquitous Computing. *Communications of the ACM, 36*(7), 79-84.

Weiser, M., & Brown, J. S. (1996). The Coming Age of Calm Technology. Retrieved from http://nano.xerox.com/hypertext/weiser/acmfuture2endnote.htm

Weiser, M., Gold, R., & Brown, J. S. (1999). The Origins of Ubiquitous Computing at PARC in the Late 1980s. *IBM Systems Journal, 38*(4), 693-696.

Wright, P., & McCarthy, J. (2010). *Experience Centered Design*: Morgan & Claypool Publishers.

Ylirisku, S., & Buur, J. (2007). *Designing with Video: Focusing the User Centered Design Process*. London: Springer-Verlag.

APPENDICES

A. INFORMED CONSENT FORM

CONSENT TO PARTICIPATE IN
NON-BIOMEDICAL RESEARCH

ITR: Detecting Activity in Homes with Ubiquitous Sensing to Support Aging in Place

You are asked to participate in a research study conducted by the following researchers from the Department of Architecture and the MIT Media Laboratory at the Massachusetts Institute of Technology (M.I.T.):

Dr. Stephen Intille, Research Scientist, Architecture
Kent Larson, Principal Research Scientist, Architecture
Emmanuel Munguia Tapia, Research Assistant, Media Arts and Sciences
Jennifer Beaudin, Research Consultant, Architecture
Aydin Oztoprak, Visiting Researcher, Architecture

You were selected as a possible participant in this study because:

- You are at least 18 years of age
- You live in an apartment or home
- You live within the Greater Boston area at a location easily accessible via public transportation
- You are not employed by the MIT Department of Architecture or the MIT Media Laboratory

You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

- **PARTICIPATION AND WITHDRAWAL**

Your participation in this study is completely voluntary and you are free to choose whether to be in it or not. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

- **PURPOSE OF THE STUDY**

The purpose of the study is to determine the feasibility of using a large number of simple sensors, distributed throughout the home setting, to recognize everyday activities. We anticipate that this study will help us to design sensors and sensor casings, improve sensor installation procedures, and develop and measure the performance of computer algorithms that can automatically detect everyday activities. This work may eventually lead to the development of new devices for the home that help people live in their homes longer as they age.

- **PROCEDURES**

If you volunteer to participate in this study, we would ask you to do one or more of the following things:

1. Have sensor devices, or just the cases that would contain such devices, installed in your home. They will be taken down within ____ days.
    a. You may be asked to install the sensors (or sensor cases) following provided instructions
    b. Or, we, the researchers, will install the sensors (or sensor cases) in your home under your supervision
2. Wear “on-body” sensors for _____ days during the experiment.
3. Have data collected about your everyday activities by the sensor devices (in your home and/or that you are wearing) for _____ days during the experiment.
4. Answer questions presented to you on a mobile device that you carry with you (also known as doing “experience sampling”) for _____ days during the experiment.
5. Permit collection of audio and/or video data of your home activities from up to five locations in your home.

These procedures are described in more detail below. Not all may be available for this experiment. The investigators have indicated those that are available under the “Payment Participation” section of this form.

<u>Procedure 1: Installation of the Sensors</u>

For the purposes of this study, up to 300 small sensor devices ,one or more laptop computers and table-like boxes (serving as a casing for the devices) will be temporarily installed in your home. These sensor devices may be installed by a team of up to four researchers, under your supervision, or, we may ask you to install these sensors yourself using a set of step-by-step instructions.

The sensor boards are 1.5 by 1.5 inches and encased in plastic. These sensors (or just their cases) will be placed or taped on furniture, appliances, and other objects throughout your home. The sensors will be attached using either conventional tape, sticky products (e.g. 3M adhesive), or, in some cases, a special glue that will not cause any damage to your belongings. The sensors will not interfere with your daily activities. These sensor devices can detect changes in activity as described under Procedure 3 below.

The table like boxes are 16 by 23 inches and have a height of 21 inches and assembled from birch plywood. On top of these boxes we have lamp post in which some of the sensors are installed. After the installation boxes will stay where they are. They don’t need any user interaction.

Our ultimate goal is to make these sensor devices easy for non-experts to use, so we may ask you to install the sensors yourself and give us feedback about the process. We will provide instructions and needed materials for the installation. Once you have installed the devices, we will document where and how you installed them. If you are participating in other procedures, we may ask if sensor locations can be adjusted and added, and we may remove other sensors.

Procedure 2: Wearing "On-Body" Sensors

During the experiment period, you may be asked to wear "on-body" sensors: lightweight sensors that can be affixed to the exterior of your body (most typically at your wrist, ankle, and hip) using wrist/anklebands or latex-free elastic bandages. These sensor devices can detect changes in activity as described under Procedure 3 below.

You may also be asked to carry a mobile computing device, such as a cell phone or handheld computer. You will be asked to wear the on-body sensors and carry the device throughout the study period, unless the investigators instruct you to remove them for sleeping, bathing, or other activities. These on-body sensors should not disrupt you from your activities or cause you physical discomfort. If the on-body sensors or mobile device do become uncomfortable, you may take them off at any time and return them to the investigators.

Procedure 3: Collection of Activity Data

The sensor devices installed in your home may consist of very simple switch, object movement, and illumination level sensors that measure the state of a door, drawer, device, or other object. For instance, a sensor placed on a cabinet door can detect when it is open or closed. A sensor placed on a chair can detect when the chair is moved. A sensor placed on a TV can detect when it is turned on or off. Each sensor device in the home wirelessly sends information about the state of the object to which it is attached to a laptop computer, where the information is stored.

The sensors that you wear on-body also record data about changes in activity, such as foot steps taken, body limb movement, heart rate, and exposure to visible and ultraviolet light. The sensors may also detect your position within your home and, if you are asked to carry a GPS device, position in your community. These devices transmit information wirelessly to the laptop computer or to a storage device that you carry with you or to the table like boxes. The combination of these sources of data provide a description of your activity during the study period. If you express to the researcher that you are uncomfortable with sensors being used in any specific location, those sensors will be removed.

Procedure 4: Experience Sampling

During the experiment period, we may ask you to carry a mobile computing device, such as a cell phone or handheld computer (i.e., PDA), with you wherever you go, including outside of your home. We will provide a special carrying case you can wear on your belt or put in your purse. The device will frequently "beep," at which time multiple questions will be presented. You can answer the questions by simply pushing buttons on the keypad or screen. This mobile device will be used to make a detailed record of your daily activities at the same time that the sensors in your home are measuring how you interact with various objects and appliances. The mobile device will *sample* your activities by presenting multiple-choice questions approximately every _____minutes. The mobile device will save your answers. At night, you may turn off the experience sampling system, so that you can rest without interruptions.

Procedure 5: Audio and/or Video Recording

During the experiment period, we may ask you to allow us to place up to five laptop computers and furniture like sensing devices in your home. These devices will be used so that researchers can manually annotate the video with your activities so that they may compare the performance of their activity detection algorithms with what you actually did during the time the sensors were installed. Each computer may have a microphone and/or camera attached to it. If you agree to this option, we will work with you to find acceptable locations for the cameras and/or microphones and we will show you what the video looks like and audio sounds like. You can request that any or all audio and video cameras not be used. We will also show you how to block the video and turn off the audio during the study as well as to log times when you would like audio and/or vide data deleted. Data you mark for deletion will be destroyed prior to any researcher viewing it.

During the experiment you will receive up to three daily telephone calls from the investigators asking if you have observed any problems with the installed sensors, the wearable sensors, and/or the mobile device. The investigators can also address any questions or concerns you may have.

At the conclusion of the study, up to 4 investigators will visit your home to carefully remove all the home sensors and collect the on-body sensors and computers.

Along with your participation in these procedures, you will be asked to complete a debriefing interview at the end of the experiment. During this interview, you may decline to answer any or all questions.

- **POTENTIAL RISKS AND DISCOMFORTS**

During the course of this study, if you are participating in the data collection procedure, you may at times feel uncomfortable about having data collected about your activities. The investigators will provide a logbook that you may use to indicate time periods for which you wish to have data disguised or erased. Data you mark for deletion will never be viewed/used by researchers prior to destruction. If you wish to discontinue data collection altogether, you may withdraw from the study at any time.

If you are participating in experience sampling, there is a possibility that you may feel stressed by the mobile device. You are free to decline to answer any of the questions that the mobile device presents to you, and you may turn off the device should it become too stressful.

If you are participating in audio and/or visual recording, there is a possibility that you may feel stressed by the recording devices. You are free to block video and/or disable audio, as the researchers will show you how to do. You may also request that the researchers remove the audio and video recording devices should that component of the experiment become too stressful.

If for any reason any damage is caused to your furniture, electric/electronic appliances, or your home in general due to the installation/removal of the sensor boards by the researchers, we will reimburse you with the amount of money equivalent to the damages caused. If you do not wish a sensor to be installed in any particular spot, you may simply not place it there and/or decline to have one placed there.

- **POTENTIAL BENEFITS**

By participating in this study, you may learn about novel technologies under development. You may also gain a deeper appreciation of the richness of your everyday activities and how they are supported by your home setting.

We anticipate that this study will help us to design sensors and sensor casings, improve sensor installation procedures, and develop and measure the performance of computer algorithms that can automatically detect everyday activities. This work may eventually lead to the development of new devices for the home that help people live in their homes longer as they age.

- **PAYMENT FOR PARTICIPATION**

We appreciate your courtesy in having the sensors or sensor cases in your home for the study period and for participating in the selected study tasks. The compensation you will receive is dependant on the specific study procedures in which you are participating. The table below lists compensation amounts for each study procedure; spaces are provided next to each procedure for 1) the investigator to indicate whether it is available for the current experiment and 2) you to indicate that you have selected to participate in the procedure.

1. Available? [investigator]	**2. Selected? [participant]**	**Procedure**	**Compensation**
		You (not the researchers) install the sensors in your home following the provided instructions	$15 (one time)
		Sensors installed in your home that collect data about your activity. You have the following sensors in your home: ☐ Object movement and position sensors; ☐ Electricity use sensors; ☐ Temperature sensors; ☐ Humidity sensors; ☐ Ambient light level sensors; ☐ Ultraviolet light level sensors	$5 per day
		Sensors that you wear to collect data about your activity. You wear the following on-body sensors: ☐ Pedometer; ☐ Accelerometers to detect body-limb motion; ☐ Skin temperature monitor; ☐ Heart-rate monitor; ☐ Ambient light monitor; ☐ Ultraviolet light (UV) monitor; ☐ Indoor house location monitor; ☐ GPS (community location) monitor	$5 per day
		You periodically answer experience sampling questions presented to you on a mobile device that you carry with you during the day	$5 per day
		You permit audio and/or video recording in your home during the study, from up to 5 locations	$5 per day

The total compensation for your participation in this study, which will last _____days, is $_____.

If you choose, you may also participate in the study *without compensation*, as a volunteer; please indicate your decision to do so by initialing one of the following blanks:
Paid _____ Unpaid_____

If you must drop out of the study because the investigator asks you to or because you have decided on your own to withdraw, you will still receive the compensation for all tasks/days completed.

- **CONFIDENTIALITY**

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.
Your responses and sensor data will be referenced by an ID number in order to protect your identity. A study enrollment log will be kept that will include participants' unique identification numbers, names, telephone numbers and enrollment data. This log will be stored in a locked cabinet in the investigators' office and will be destroyed 1 year after the completion of the study.
When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity. Your name will not in any way be associated your data, including photographs, audio and video recordings. Once your data is anonymized, it may be shared with other researchers for future studies.
Investigators may take still photographs of your home environment, including objects on which they (or you) have installed sensors. With your permission, they may video-tape or audio-record the sensor installation and the post-experiment interview. If you do not wish to be videotaped, audiotaped or have pictures taken of you or your home environment, you may still participate in this study without prejudice. During the study, you can ask the investigator at any time to stop the audio recording and videotaping. You may review any photographs, videotape or audio-recording taken during your experiment and request that tapes be erased or digital images be deleted.
The videotapes, audiotapes, and photographs will only be used by the investigators for the data analysis tasks of the study and to document that work in academic publications. The media will be under the sole control of the investigators and will be stored in a location accessible only to the investigators. After the investigators have analyzed the results, prior to showing any images or audio in academic and peer-reviewed papers, or anywhere else, they will use standard methods to manipulate the media to protect your identity, such as blurring the face. Any media that cannot be appropriately anonymized will be destroyed within one year after completion of the study.
Please indicate your consent to have still photography, audio recording, and video taping, during the sensor installation and/or post-study interview by initialing below:

Audio/Video/Photo Consent for Sensor Installation: _____ Decline: _____
If you are participating in in-home audio and/or video recording, please indicate your consent to have still photography, audio recording, and video taping, during the experiment from up to five locations within your home agreed to by you and the researchers:
Audio/Video/Photo Consent During Experiment: _____ Decline: _____

- **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about the research, please feel free to contact

Stephen Intille, Ph.D.
Research Scientist, MIT Dept. of Architecture
617-452-2346, intille@mit.edu
Kent Larson
Principal Research Scientist, MIT Dept. of Architecture
617-253-9396, kll@mit.edu
Emmanuel Munguia Tapia
Research Assistant, MIT Media Laboratory
617-452-5640, emunguia@mit.edu
Jennifer Beaudin
Research Consultant, MIT House_n
617-452-5677, jbeaudin@mit.edu
Randy Rockinson
Research Assistant, MIT Media Laboratory
617-452-5640, rockinso@mit.edu
Aydin Oztoprak
PhD Student Visiting Researcher, MIT Dept. of Architecture
617-452-5640

- **EMERGENCY CARE AND COMPENSATION FOR INJURY**

"In the unlikely event of physical injury resulting from participation in this research you may receive medical treatment from the M.I.T. Medical Department, including emergency treatment and follow-up care as needed. Your insurance carrier may be billed for the cost of such treatment. M.I.T. does not provide any other form of compensation for injury. Moreover, in either providing or making such medical care available it does not imply the injury is the fault of the investigator. Further information may be obtained by calling the MIT Insurance and Legal Affairs Office at 1-617-253 2822."

- **RIGHTS OF RESEARCH SUBJECTS**

You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you feel you have been treated unfairly, or you have questions regarding your rights as a research subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143b, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253 6787.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Subject

____
Name of Legal Representative (if applicable)

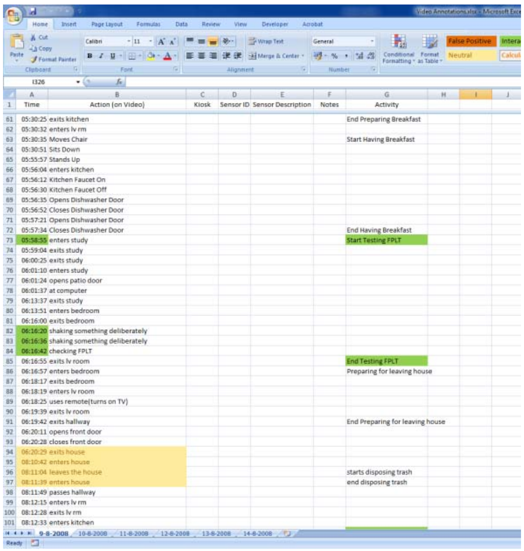
____ _______________
Signature of Subject or Legal Representative Date

SIGNATURE OF INVESTIGATOR

In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____ _______________
Signature of Investigator Date

B. DATA ANALYSIS OF THE FIRST CASE STUDY



	Time	Action (on Video)	Kiosk	Sensor ID	Sensor Description	Notes	Activity
61	05:30:25	exits kitchen					End Preparing Breakfast
62	05:30:32	enters lv rm					
63	05:30:35	Moves Chair					Start Having Breakfast
64	05:30:51	Sits Down					
65	05:55:57	Stands Up					
66	05:56:04	enters kitchen					
67	05:56:12	Kitchen Faucet On					
68	05:56:30	Kitchen Faucet Off					
69	05:56:35	Opens Dishwasher Door					
70	05:56:52	Closes Dishwasher Door					
71	05:57:21	Opens Dishwasher Door					
72	05:57:34	Closes Dishwasher Door					End Having Breakfast
73	05:58:55	enters study					Start Testing FPLT
74	05:59:04	exits study					
75	06:00:25	exits study					
76	06:01:10	enters study					
77	06:01:24	opens patio door					
78	06:01:37	at computer					
79	06:13:37	exits study					
80	06:13:51	enters bedroom					
81	06:16:00	exits bedroom					
82	06:16:20	shaking something deliberately					
83	06:16:36	shaking something deliberately					
84	06:16:42	checking FPLT					
85	06:16:55	exits lv room					End Testing FPLT
86	06:16:57	enters bedroom					Preparing for leaving house
87	06:18:17	exits bedroom					
88	06:18:19	enters lv room					
89	06:18:25	uses remote(turns on TV)					
90	06:19:39	exits lv room					
91	06:19:42	exits hallway					End Preparing for leaving house
92	06:20:11	opens front door					
93	06:20:28	closes front door					
94	06:20:29	exits house					
95	08:10:42	enters house					
96	08:11:04	leaves the house					starts disposing trash
97	08:11:39	enters house					end disposing trash
98	08:11:49	passes hallway					
99	08:12:15	enters lv rm					
100	08:12:28	exits lv rm					
101	08:12:33	enters kitchen					

Figure 50 Sample annotation file

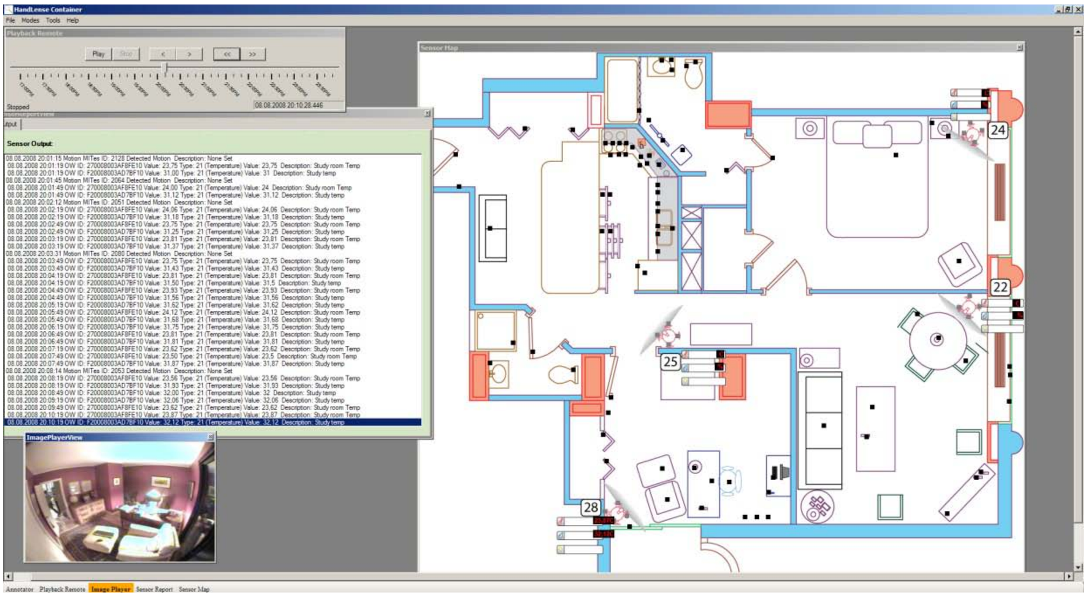


Figure 51 Handlense screen capture

C. DATA ANALYSIS OF THE SECOND CASE STUDY

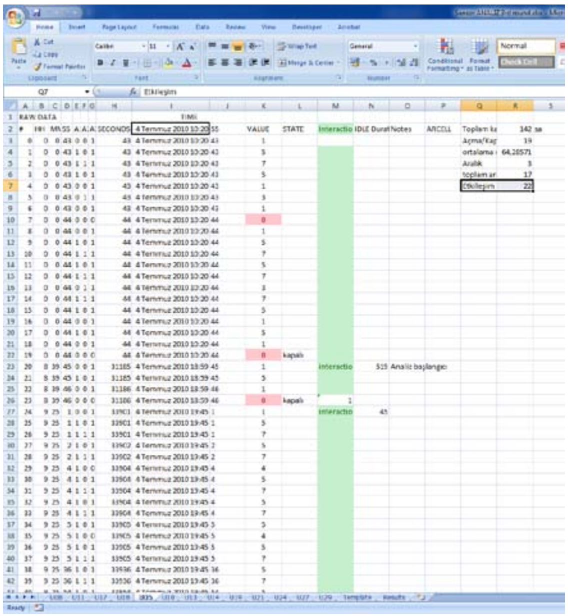


Figure 53 Analysis Software for data transmitter in second case study

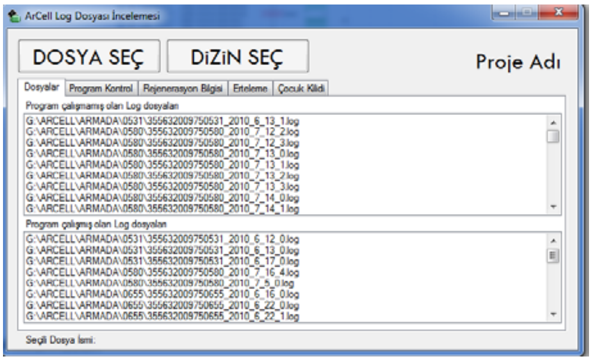


Figure 52 Sample annotation file for second case study

CURRICULUM VITAE

Personal Information

Surname, Name: Öztoprak, Aydın
Nationality: Turkish
Date and Place of Birth: 20 October 1978, Bolu
Marital Status: Single
Phone: +90 532 5615663
Email: info@aydinoztoprak.com
Web Site: www.aydinoztoprak.com

Education

MS METU Department of Industrial Design 2004
BS METU Department of Industrial Design 2001

Work Experience

2009- Present	TOBB ETU Department of Industrial Design, Instructor
2007-2008	MIT Media Lab, Visiting Researcher
2001-2007	METU Department of Industrial Design, Research Assisstant

Foreign Languages

Advanced English

Publications

- In D. de Waard, K.A.Brookhuis, and A. Toffetti (Eds.)(2006), Developments in Human Factors in Transportation, Design, and Evaluation. *Field versus laboratory usability testing: A first Comparison* (pp. 205-212). Maastricht, the Netherlands: Shaker Publishing.
- Oztoprak A., Erbug C. (2005) An Evaluation of an Online Collaborative Course. In Proceedings of Human Computer Interaction 2005 Conference Vol 6. Las Vegas NV. USA.
- Akar E., Oztoprak A. TunçerB. (2004) Evaluation of a Collaborative Virtual Learning Environment. In Proceedings of E-learning International 2004 conference. Glasgow – Scotland.