User involvement in the development of smart assistive technologies

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Abstract

The rapid growth of the aged population puts inevitable strains on health services and support networks worldwide. This growth continually increases the financial expenditure for physical care, not only because of a growing demand, but also because of an insufficient availability of professional caregivers. In addition, older adults have an increased need for the provision of care at a convenient location, which is most frequently in their own home and not in a nursing- or elderly home. Therefore, there is a growing interest in technologies, which can both supplement and/or replace high quality care at home. This technology is generally referred to as smart assistive technologies, or smart ATs.

However, designing these smart ATs, particularly for the biggest group of potential users, is not a straightforward process. The proper consideration of abilities, disabilities, needs and desires of potential users is crucial for the success of these products. In current literature, two main differences of approach can be established. The first difference occurs between the broadness of definition of users being only end-users or also 'additional' users, such as professional caregivers, informal caregivers and relatives. The second difference is discernible when creating a proper 'image' of potential users. Design literature puts forward the idea, that users ideally should be physically involved in the developmental process, while innovation literature suggests that users can also be represented by 'other sources of use information', such as experts.
During the course of this research, I interviewed people involved in the development processes of smart assistive technologies in The Netherlands. The goal of these interviews was to give an informed answer to the main research question I have pursued:

> *When and how is information about (potential) users of smart assistive technologies (smart ATs) brought into the design and development processes of smart ATs in The Netherlands?*

An attempt was made to determine which of the two design strategies is preferred by developers, and why this strategy is legitimate in creating an 'image' about potential users and use. Additionally, the way in which developers consult different sources of information (and how these sources obtain information on use and users) is explored.

Results show that the majority of current developers of smart ATs in the Netherlands consider both older and younger adults as their potential users. Because of the nature of smart assistive technologies, this is a striking phenomenon. Developers working on developmental processes of more complex technologies (which in this study were the technologies frequently related to healthcare) also assigned importance to additional users. Both rationales given for considering additional users, or explicitly ignoring them, seem to be legitimate. This means that at least some development processes benefit from the broader definition of users, as advocated by innovation literature. In addition, the results show that most development processes do not apply user participation as advocated by the practical design literature, because it is expensive, time consuming and the expected benefits are limited. Instead, developers rather apply other sources of use information to create an 'image' about use and users, such as consulting experts or applying knowledge that was obtained during previous experience and/or research. These sources of use information are considered equally (or sometimes even more) useful and valuable when creating an 'image' of users and use and they are considerably cheaper and less time consuming.

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1 Introduction

The proportion of elderly people within the total population is increasing, which is a phenomenon not only characteristic for The Netherlands, but also for the majority of European countries (Fisk et al., 2009; Ponsard et al., 2008; Mann et al., 2005). For The Netherlands, it is estimated that by the year 2039, 25.7% (over 4.4 million people) of its population will be over 65 years of age. Currently, around 2.4 million people are over 65, which is 15% of the total population (Centraal Bureau voor de Statistiek, 2009). This increase in the share of the aged population is a trend (Fisk et al., 2009; Lawson, Nutter, & Wilson, 2007), which will put an inevitable strain on health services and support networks (Mann et al., 2005).

Up to now, when people (older adults[1]) face problems of a physical or mental nature, they have to either move to a nursery home (elderly home) or in limited cases receive care at home. However, because the cost of care in residential and nursing homes increase, and people in general (and older adults in particular) have an increasing need for choice in the location of care (which in many cases is not in nursing- or elderly homes), there is a growing interest in ways of supporting people in their own homes. Additionally, numbers of professional caregivers are decreasing, which means that older adults will have to cope with less physical care or replace this physical care with other solutions that address their needs (Doughty et al., 2007). Therefore, interest is growing in the role technologies can play in prolonging the independence[2] of older adults, by helping them with basic daily tasks. This is often referred to as 'assistive technologies' (ATs) (Malanowski, Özcivelek, & Cabrera, 2008; Ponsard et al., 2008; Lawson, Nutter, & Wilson, 2007; Soprano, 2006a, 2006c, 2006b). Traditional forms of ATs range from cheap, low-tech and portable devices (such as walking sticks, spectacles and tap turners) to more expensive fixed adaptations to the home (like stair-lifts and ramps). More recently, ATs started to depend more on and include innovations in electronics, computing and telecommunications, like environmental controllers enabling disabled people to operate electrical applications through a personal interface arrangement. With the inclusion of electronics, computing and telecommunications in ATs, the ATs become 'smart' ATs, which increases the potential solutions for older adults to remain autonomous (Doughty et al., 2007).

However, one might wonder how these smart assistive products relate to the better-known concept of smart-homes. When smart ATs are products that assist people in their daily tasks, smart homes are constellations of these smart ATs, combined with other smart products. Smart home projects used to be aiming on smart products for the 'wealthy few' as its market, but currently an increasing number of smart home projects also include smart ATs for older adults as a potential market (Rijsdijk & Hultink, 2003). Smart Homes (also referred to as domotica, automated or intelligent homes, integrated home systems or ambient intelligence) incorporate devices that control features of the home environment, which are often referred to as 'smart products' and are based on electronics, computing and telecommunications (Schuurman et al., 2007; Mann et al., 2005). Smart home technology started as a technology to control environmental systems like lighting and heating, but currently other electrical components within a house can also be included. This technology is capable of not only turning equipment on or off, but also monitoring the internal environment and the activities being undertaken, which enables smart home technology to respond and react independently. Safety of the people within the house can be improved in this way, by for example enabling the system to contact emergency services (Dewsbury & Edge, 2000). In general, smart products (and thus also smart ATs) show at least one of the following characteristics (Rijsdijk & Hultink, 2003):

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[1] The term 'older adults' is used for people over 65 years old, because it is suggested to be the most polite and appropriate term (Fisk et al., 2009; Bechtold & Sotoudeh, 2008; Harwood, 2007; Mann et al., 2005)

[2] Independence is defined as the ability to complete basic daily tasks (activities of daily living (ADL) like eating and dressing, and instrumental activities of daily living (IADLs) like shopping and managing one's house) and leisure activities, without personal assistance (Mann et al., 2005).

- able to communicate with other products (e.g. a digital camera with personal computers),
- able to process information (e.g. a heat thermostat that takes into account the outside temperature before switching on), or
- able to perform tasks autonomously (e.g. a lawnmower that measures the length of the grass, and based on that, decides to mow the lawn).

When these smart products additionally have the intent to enhance a person's well being by enabling the basic needs of users to live individually and integrated in society, they are called 'smart assistive technologies' (smart ATs) (Bechtold & Sotoudeh, 2008). These smart ATs are very useful in enhancing autonomous living of particularly older adults, and being most promising to becoming a solution for the rapidly ageing population, the development process of smart ATs is the focus of this thesis.

Designing smart products however, is not a straightforward process. Especially not, when users' well-being depends on the quality and acceptance of design and functionality of these products (Fisk et al., 2009). Therefore, it is widely recognized in literature that users should be involved in the design and developing processes of innovative products in general (Haddon, 2002; Hippel, 1988) and smart innovative assistive products in particular (Fisk et al., 2009; Iivari, 2006; Kujala, 2003). Moreover, when referring to the involvement of users, some authors not only refer to end-users, but also to 'additional users' (like their caregivers, either professional or informal, or relatives), because smart ATs sometimes not only have an impact on older adults (Oudshoorn & Pinch, 2005). This research investigates how developers in the smart AT field actually define their (potential) user group.

Additionally, various writers frequently differ on how users should be represented. Users can be involved in a development process by physically attending development processes and 'working together' with developers (Fisk et al., 2009; Iivari, 2006; Kujala, 2003; Noyes, Starr, & Frankish, 1996), but users can also be involved through mediators or represented by experts (Peine, 2007; Haddon, 2002). In the latter case, developers consult people with knowledge about potential users to create an 'image' of the (potential) user, which will help developers to create useful products for them. Nevertheless, these forms of indirect user involvement are by many not recognized as useful sources of use and user information (Peine, 2007). The aim of this research is to gain understanding on how developers (designing and developing smart ATs) involve their potential users in design and development processes. The guiding questions that are addressed in this thesis are the following:

Main research question:

> *When and how is information about (potential) users of smart assistive technologies (smart ATs) brought into the design and development processes of smart ATs in The Netherlands?*

Sub research questions:

1. *Which potential users of smart ATs are considered during the development process of smart ATs in The Netherlands?*
2. *When is which source of use information consulted in the development process of smart ATs in The Netherlands?*
3. *When would which source of use information ideally be consulted in the development process of smart ATs in The Netherlands?*

The third sub research question is asked to determine whether the strategy of developers concerning the consulted sources of use information is actually the preferred strategy, or that in an ideal situation other sources would have been consulted as well. This could clarify for example whether some indirect forms of user involvement are second best substitutes for direct user participation, or that these indirect forms are actually the ideal sources of use information.

Up to now, the body of literature on user-producer interactions mainly focused on industry-industry interactions (Peine, 2007). This research however extends these theories by investigating interactions between producers and consumers, according to innovation- and design literature. Literature originating from innovation studies or from the more practical design studies both agree on the importance of user involvement during innovation processes (Fisk et al., 2009; Peine, 2007; Iivari, 2006; Kujala, 2003; Haddon, 2002; Hippel, 1988). They differ though in how to define users and which forms of user involvement are to be consider useful (Peine, 2007). While the design literature restricts its definition of users only to end-users, the innovation literature has a much broader definition of users being both end-users and additional users (Oudshoorn & Pinch, 2005). User participation, which is advocated by the design literature, is often proven successful during industry-industry interactions (Lin & Shao, 2000), and therefore it is considered preferable during producer-consumer interactions as well (Fisk et al., 2009; Iivari, 2006; Kujala, 2003). Most innovation literature though, not only expects developers to additionally apply other types of user involvement, but sometimes even replace user participation with other types of user involvement in producer-consumer interactions (Peine, 2007; Haddon, 2002). They advocate that both the broader definition of users and the many differences within the group of end-users in producer-consumer interactions make it apparent that involving users is not as straightforward as is generally advocated by the design literature. This research explores and collates the current manifoldness through which users are involved during the development processes of smart ATs and qualifies and/or complements the existing literature about user involvement during innovation processes. The description of the experiences of companies involved in the development of smart ATs additionally may improve development processes of consumer products in general, as well as the development processes of smart ATs in particular. It could stimulate policy makers to better facilitate user involvement, which could increase the acceptance of smart ATs and contribute to a solution of the difficulties emanating from the fast growing proportion of not only Dutch older adults, but also older adults elsewhere.

1.1 Thesis outline

A discussion of the current theoretical discourses on user involvement is presented in chapter 2. Section 2.1 elaborates on the question of which users can be considered relevant, while section 2.2 and 2.3 elaborate on how this ‘image’ of potential users is created according to the innovation literature (section 2.2) and the more practical design literature (section 2.3). Section 2.4 presents a model of possible sources of use information that guides this research.

In chapter 3 information is presented on smart AT development processes that are currently taking place in The Netherlands (section 3.1) on different levels of complexity of smart ATs (section 3.2), and on the main underlying technologies (section 3.2.1). This will enable a better understanding of the case-summaries in appendix C and of the case-group descriptions in section 5.1, and assist and guide the categorization of the cases into case-groups.

How this research was carried out is discussed in chapter 4. This chapter is subdivided into how the cases were selected and what the case-boundaries were (section 4.1). How the data was collected, and how this data was categorized/ordered into three case-groups and subsequently analyzed, is described in section 4.2 and 4.3.

Chapter 5 starts with a description of the three case-groups (section 5.1.1-5.1.3). Subsequently, sections 5.2.1-5.2.3 present and discuss the results around the three sub research questions. Section 5.2.4 mutually compares the three case-groups, and presents additional insights in the cases that were investigated.

Chapter 6 discusses the results of this research and their possible theoretical implications, in terms of which users are considered, why specifically these users are considered and how this relates to the theoretical propositions as discussed in chapter 2 (section 6.1). Section 6.2 relates the empirical results of chapter 5 with the theoretical propositions of chapter 2 and elucidates current theoretical discourses.

In chapter 7, answers to the earlier mentioned research questions are presented (section 7.1), and recommendations are made for further research (section 7.2).

2 Theoretical framework

This chapter discusses the theories that were applied about user involvement, in terms of how users are defined (section 2.1) and involved, according to the innovation literature (section 2.2) and the more practical design literature (section 2.3). This discussion not only results in a discourse of the differences present in the literature, but also clarifies the relevance of the research questions presented in the introduction.

2.1 Types of users

The introduction of this research already stressed the importance of obtaining information about potential use of a product during a development process. However, it is indispensable to elaborate somewhat on how the users of smart assistive technologies are actually defined by developers of smart ATs.

Older adults are considered to be the most important group of users of smart ATs (Fisk et al., 2009; Mann et al., 2005), which makes it inevitable to describe and define this group more precisely. However, defining a person as being an 'older adult' is not straightforward. There is no predefined boundary between adults considered 'young' or 'old', which makes 'young' and 'old' not clearly represented by age. Most research however defines older adults to be individuals over 55 (Celler, Lovell, & Chan, 1999) or 60 years of age (Fisk et al., 2009). In addition, the group of older adults is not a homogeneous group (Cheek, Nikpour, & Nowlin, 2005). Individual differences are common, regardless the decade of adult life. The particular task or situation is also important when defining persons as older adult. For example, a factory-worker will be considered 'old' if he is over 40, while that same factory-worker is not considered 'old' as a car-driver. When considering design though, Fisk et al. (2009) stress that one should focus on "those similarities that allow us to optimize the design" (Fisk et al., 2009, p. 9), without losing the awareness of the individual differences that determine who a design can or cannot accommodate. This research therefore will not only determine if products are designed only for older adults, but it will also describe how designers deal with this heterogeneous character of potential users of smart ATs.

When use of an innovation relies on well-developed capabilities of consumers in the field of ICT, and/or if market introduction will take multiple years, (which is often the case with development processes of smart ATs), it might be more appropriate to involve future users of the innovation instead of current older adults. These middle-aged[1] users have higher levels of experience with ICT and are more likely to become (potential) users.

Older adults (or future older adults) are however not the only persons affected by smart ATs. Other groups within the 'community' of older adults can be considered as 'additional users', because they have some sort of interest in either the functionality or design of the smart AT. Relatives (and especially when they provide voluntary aid), can be concerned with the well-being of e.g. their parents, and feel a certain level of responsibility for their safety. In that case, smart ATs should not only help the older adults, but also address the needs of these informal caregivers. Formal caregivers (nurses, doctors, pharmacists) are professionally responsible for the well-being of older adults. So when smart ATs replace, enhance or contribute to some of their tasks, these formal caregivers also have to rely on the quality and ease of use of smart ATs, which make them users of the innovation as well (Oudshoorn & Pinch, 2005).

[1] This age-group is broadly defined as adults between 45 and 65 years of age (Noller, Feeney, & Peterson, 2001)

This broader definition of users is put forward by authors addressing innovation research, because it can assist in explaining why some innovations become a success while others do not. However, the idea that end-users are not always the only 'users' of a product, is in general ignored by the more practical design literature of human-factor-professionals. The tension between these two bodies of literature is addressed by sub research question 1, which determines not only how developers of smart ATs in The Netherlands define potential users of their products, but also why they define users as they do, and what the theoretical implications of this could be.

2.2 Sources of use information

Since the 1970s, theoretical explanations of technical change and innovation have evolved considerably[1]. In traditional theories, the emergence of new technologies is explained by either a result of technology-push (Schumpeter) or demand-pull (Schmookler) (Peine, 2007). Manufacturers invest in new technologies when new technological opportunities occur, or when there is an unaddressed need in the market. More recent studies though have argued this view of technological change, by showing that innovation is a process that interacts with both the demand and the supply side simultaneously (Dosi, 1988; Nelson & Winter, 1982). Two particular critics on demand-pull models of innovation, put forward by Mowery and Rosenberg (1979), are that they do not address demand itself, but rather less strictly defined notions of 'latent' or 'anticipated' user needs. User needs are not the same as market demand, because user needs do not only refer to the quantity of a market, but also to its quality (Peine, 2007). Reviewing different bodies of literature that have looked at the forms of interdependent relationships and learning between the market, users, and manufacturers, Peine (2007) concludes that innovation "is a process that is distributed about manufacturers and users, and that combines information from the sites of manufacturers and users" (pp. 8-9). However, while knowledge about design and production is widely described in literature about technological change and innovation, less attention is given to use and demand, while the combination of the two is of major importance in creating successful innovations (Peine, 2007). Innovations can also come primarily from users, as discussed by Von Hippel (1988), but this is not very likely in the field of smart ATs, as potential users of these technologies lack necessary levels of specific technological knowledge needed to be able to create new technological opportunities (i.e. potential users are not very likely to show lead user characteristics). Therefore, this research restricts itself to assuming manufacturers to be the source of innovation, while both manufacturer and users can be the source of use information.

According to Peine (2007), five different types of user involvement in manufacturer innovations can be observed (Figure 1): non-representation, implicit representation, indirect representation, direct representation and user participation.

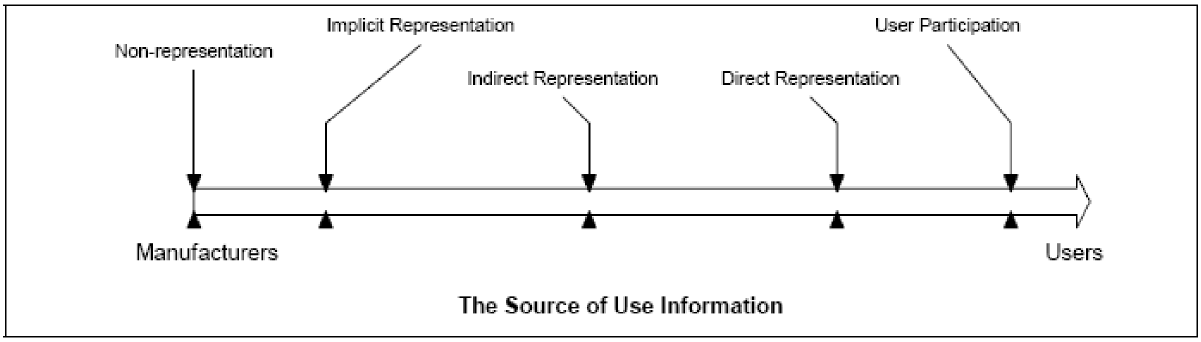

Figure 1: Types of user involvement for manufacturer innovation (Peine, 2007).

[1] For a complete review on relevant literature about technical change and innovation, and an exploration into innovation and aging, I would like to refer to Peine (2007).

As figure 1 shows, these types can be interpreted as a continuum of increasing intensity of co-development of products, between manufacturers and users. The first type of user involvement is when no users are involved in the innovation process, referred to as non-representation. Instead of relying on information of use from (potential) users, designers either refer to their own preferences and skills (also called I-methodology), or refer to anecdotal information about use coming from the designers' professional network. The boundary between the previous source of use information and implicit representation is not very rigid and not easy to discriminate from. Implicit representation occurs when there is no deliberate representation of either use or users, but a representation of users and use is constructed, based on earlier attempts to gain insight about them. When designers participated in developing products that had similar use or users in the past, they will copy the insights gained about users or use of previous design processes to the present one. With indirect representation, users are represented by others than the users themselves (e.g. experts). This representation is based on general knowledge about users and use, which might be adopted within a specific innovation project, but which is not based on actual empirical investigations of (potential) users and use in that specific innovation project. When these experts do base their information on empirical investigations of (potential) users and use in the specific context of an innovation project, this is called direct representation. The experts in this latter case act as mediators between real users and the process of design, and have direct contact with both designers and (potential) users. User participation occurs when users physically participate in the innovation process, which implies that users are actually invited to the site of the manufacturer to discuss the design together with the designers (Peine, 2007).

The previous discussed continuum of sources of use information only shows increasing levels of intensity of co-development between users and developers/manufacturers. It does not represent a normative scale on which increasing levels of intensity means better development practice (Peine, 2007). Reasons why intense levels of co-development are not always preferred are the high demands and costs for manufacturers related to these forms of user involvement, and the inability of users to be able to 'understand' future use in all cases. Some forms of innovation, especially radical ones, relate to such radical new concepts (for example in terms of ways of living, or ways of working), that users cannot imagine how products can be used in the future or how these products could assist them and be of any benefit. Obtaining useful insights from intense sources of use information is in these cases thus very hard and, because of the necessary resources (both financial and human), most likely to occur (when possible) in innovation processes that are initiated and/or owned by larger companies.

2.3 Design approaches

However, the innovation literature discussed thus far calls into question some of the assumptions running through the more practical design literature, which advocates that direct user involvement is the most ideal form of user involvement during innovation processes (Fisk et al., 2009; Iivari, 2006; Kujala, 2003; Noyes, Starr, & Frankish, 1996). The following section elaborates further on their reasoning.

Many design approaches are design-centered, because of overconfidence of the designers and/or management pressure. Overconfidence occurs especially when new products are based on previous ones (most new products are actually follow-ons to a previous product). Designers' experiences in the development of previous versions of the product make them believe that this information is sufficient for producing a new design. Additionally, management exerts pressure on designers to produce new products in shorter development times while allocating insufficient resources for addressing user needs. This causes designers to put less effort in researching (potential) users and/or consider future use of the product. However, the reduction of development time should actually be an even stronger reason why elaborate use and user research should be integrated into a design process, because it most likely leads to the production of "the most usable product feasible as rapidly as possible" (Fisk et al., 2009, p. 30).

The most commonly advocated design approaches are *participatory design* (PD) (also referred to as co-operative design), *ethnography*, *contextual design* (CD), and *user-centered design* (UCD) (also referred to as usability engineering) (Kujala, 2003). *Participatory design* is the result of collaboration between designers and workers on “understanding users and their tasks when planning and designing new business practices and interfaces. Users … analyze the organizational requirements and plan appropriate social and technical structures to support both individual and organizational needs” (Kujala, 2003, p. 3). *Ethnography* describes human activities and culture, while focusing on social aspects of human co-operation. It aims at understanding the current work practices of potential users of a product thoroughly, before starting the design phase of new products. *Contextual design* (CD) studies users at the location of their activity, by watching and talking with them about their activity while they perform their activity in their own environment. Obviously, this occurs primarily with one user at a time, and the main idea of this approach is to be able to describe and redesign the work processes by “changing role structures, supporting tasks, and automating and eliminating unnecessary steps” (Kujala, 2003, p. 4). The final and most frequently advocated design approach is that of *user-centered design* (UCD). UCD has many similarities with previously mentioned approaches (Kujala, 2003), but UCD is considered to be more complete and most appropriate when designing for older adults (Fisk et al., 2009). User-centered design processes can be described by the following four principles (Fisk et al., 2009, p. 29):

1. “Early focus on the user and the tasks the user will be performing […],
2. Empirical measurement using questionnaires and surveys as well as usability testing studies that rely on observations and quantitative or qualitative performance data,
3. Iterative design and testing, which often requires the development of prototypes of products or system interfaces to support trade-off decisions,
4. Integrated design, wherein all aspects of the usability design process evolve in parallel and are generally under the coordination of a single person.”

Summarized, previously described design approaches clearly state that the highest levels of intensity of co-development between users and developers/manufacturers (i.e. user participation) are highly preferred, because they result in better usable products and decrease development time. Although innovation literature agrees with the importance of creating a correct ‘image’ of potential use and/or users, it also considers other forms of user involvement useful, because it does not agree with the restricted definition of users utilized by the design literature. The design literature’s rather limited definition of users being only end-users, and their focus on the similarities within the group of end-users, makes it understandable why they consider direct user participation to be the ideal form of user participation. However, if one defines users as both being both end-users and additional users, and when you consider the group of end-users to be highly heterogeneous, direct user participation can become very complicated, costly, and sometimes even impossible.

2.4 Conceptual framework

In the previously described theories on user involvement, it became clear that there is a difference in literature on what kind of co-development between users and developers is preferred during the development of products. By addressing sub research question 2 and 3, this research presents insights into this discourse, by investigating which intensities of co-development actually occur (i.e. what kind of sources of use information are applied) in development processes of smart ATs within The Netherlands, and if developers ideally would have applied other sources as well or some sources instead of others.

This research allocates the applied sources of use information during the development of smart assistive products to the continuum of sources of use information as proposed by Peine (2007). However, in the course of this research, it transpired that it is very difficult to determine if developers based their design fully on own preferences and skills (non-representation), because they do not generally acknowledge this as their working practice. If they do not involve users (directly or indirectly), they declare that they ground their design-choices on (market) research (either specifically for a development process or in general about their potential market) and/or on previous experiences in comparable development processes (implicit representation). Therefore, for this research these two types of user involvement are combined into ‘non- & implicit representation’. The theoretical difference between direct and indirect user involvement (i.e. experts basing their representation on an empirical investigation of users and use in the specific context of an innovation project, or on expertise about users and use in general), was very difficult to observe in the empirical field addressed in this research. Therefore, these two types of user involvement were combined into one (direct & indirect representation), and all user representation through experts was allocated to this type of user representation. In addition, a group named 'ordering customer involvement' was added. Ordering customers give a company the order to develop a smart AT and developers consider them knowledgeable about the potential users of the product under development. However, most of the time, they are not in close contact with users, but are either managers of (home) care institutes or building owners, which does not necessarily make them user-experts. Therefore, this type of user involvement was not allocated to the category of direct & indirect representation, but a separate category was created. The final change to the model proposed by Peine (2007), was the differentiation being the applied sources of use information into sources applied before prototyping and after prototyping, which is in line with the reading and writing metaphor of Woolgar (1991)[1]. Considering these alterations, this resulted in a continuum of increasing intensity of user involvement, as depicted in figure 2.

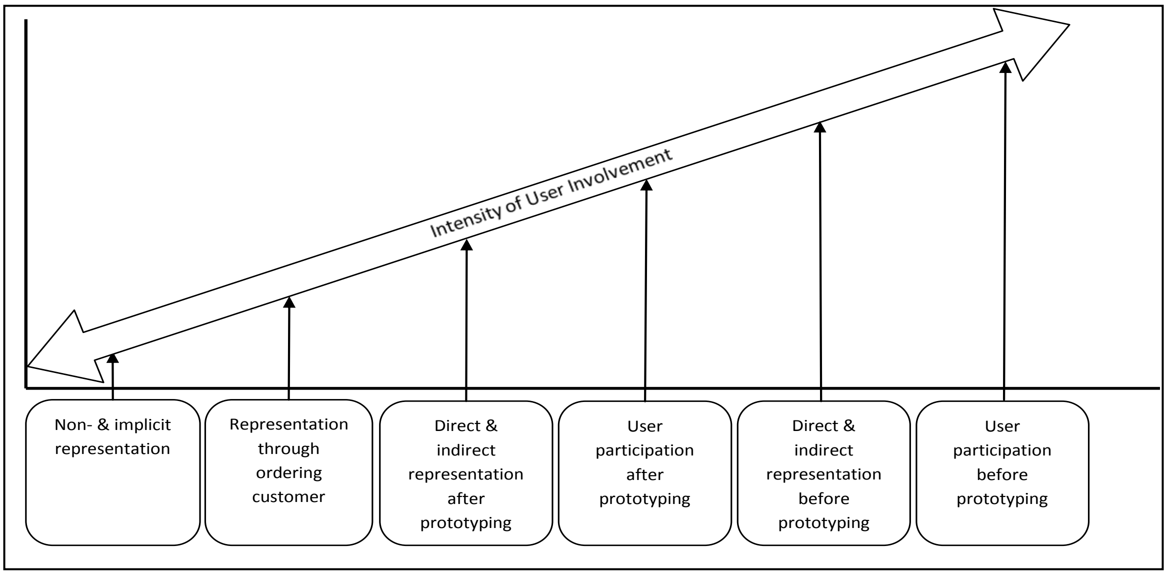

Figure 2: Sources of use information

As figure 2 shows, indirect representation, direct representation and user participation can occur both before and after prototyping. Experts, mediators and users can be involved by assessing and testing prototypes, but they can also be involved before prototyping by assessing the concepts, ideas, and possibilities of the innovation. As non- & implicit representation and representation through ordering customer is not specifically applied either before or after prototyping, this difference is not made. It is assumed that representation through ordering customer is less intense than direct & indirect representation or user participation both before and after prototyping. Because this researcher strived to depict a figure as uniform with the original model of Peine (2007) as possible, the addition of the 'time-dimension' before and after prototyping makes it more demanding to interpret. It is therefore important to realize that it does not represent any time-line, nor opposes a rating of preferred source of use information. Although the intensity of co-development between users and manufacturers increases from 'non- & implicit representation' at the left to 'user participation before prototyping' at the right, this research will empirically explore and discuss if this intensity of co-development runs parallel with the preferred sources of use information.

[1] Woolgar (1991) describes a development process by using a metaphor of creating text. Before a prototype has been established, a development process is in its writing stage. By the time a prototype has been created, it will be tested and used by potential users, which Woolgar refers to as the reading phase.

3 Technical background

This chapter describes current developments in The Netherlands related to smart ATs in section 3.1, and subsequently discusses the different levels of complexity of smart ATs in section 3.2 and some underlying technologies of smart ATs in section 3.2.1.

3.1 Smart AT development in The Netherlands

Smart assistive technologies have a growing potential in the Dutch market of older adults. Currently, life expectancy in The Netherlands is 79.4 years, which is not only one of the highest in the world, but is also expected to rise even further in the future (Central Intelligence Agency, 2009). Overall market potential of smart assistive technologies is difficult to predict, because some products are specifically developed for older adults, while others are also developed for younger adults. While the European Union makes large amounts of financial resources available for the development of smart ATs (Europa; Gateway to the European Union, 2009), this is, despite efforts of the Dutch government to actively stimulate innovation in the healthcare sector by reducing the financial constraints (Ministerie van Volksgezondheid Welzijn en Sport, 2009), still very limited in The Netherlands. Initiatives of the Dutch government to enhance innovations in the healthcare sector are the 'Healthcare Innovation Platform' (Zorginnovatieplatform), and the Healthcare Innovation Pointer (ZorgInnovatieWijzer), both established in 2008. However, both institutes are mainly focused on evaluating industry-initiatives and making small amounts of financial resources available for pilot-projects (Zorginnovatieplatform, 2009).

Looking at the Dutch industry of smart assistive technologies, many initiatives and collaborations can be observed. Already in 1998 the foundation of smart Homes (Stichting Smart Homes) was established, with the goal both to stimulate cooperation between firms developing smart products, and to create physical examples of how smart homes can take form and how they could enhance peoples' well-being (Stichting Smart Homes, 2009). Currently, innovations in the healthcare sector in The Netherlands are mainly driven by the industry, and the interviews conducted for this research more often showed proof of a hampering Dutch government (in terms of a lack of available financial resources and outdated legislation), rather than a stimulating one. Additionally hampering are projects using products labeled as 'domotics'. Because of many unsuccessful projects over the past years, 'domotics' received the connotation of being unreliable, very expensive and not helpful for people in general and older adults in particular.

Within the P&D (platform & domotics) case group, the mentioned companies are largely the key-players of this technology; however, within TTA- (track, trace and alarm) and SMD (smart medical equipment) -case groups key-players are not (yet) identifiable[1]. The high novelty factor of SMD-technology makes it difficult to determine which of the companies is currently developing the most promising technology. In addition, the limited number of Dutch companies involved in developing this technology at the moment could indicate that Dutch companies are not pioneers in this field. With TTA-cases, the lack of a clear indication of key-players is different. If one investigates the current alarm market in The Netherlands, probably only products of foreign companies like Tunstall and Bosch will be found. Apparently, Dutch companies only recently have entered this market and therefore it is too early to tell if one of them will become a key-player.

3.2 Smart assistive technologies

Smart Assistive Technologies (ATs), which are assistive technologies based on information and communication technologies (ICT), are not a fully new phenomenon. Basic Smart ATs, like blood pressure monitors, computers, the internet, telephone, automatic beds, and hearing aids are part of many older adults' daily routine. In addition, activities of older adults increasingly involve the use of some form of technology, which offers the potential to "help older adults to be actively involved in the management of their own healthcare and to access

[1] Section 5.1 clarifies how these case-groups are defined

information about health or available resources" (Fisk et al., 2009, p. 125). The most common categories of technology currently used by older adults are medical devices and communication equipment (Fisk et al., 2009), but it is likely that more categories will be used in the future (Mann et al., 2005). This chapter will describe the increasing levels of complexity smart ATs can have, which is specified in the table 1.

Level	**Description of smart AT products**	**Examples**
1	Offers basic communication	• Interactive voice and text communications (phone & email) • Provides links to the World Wide Web • Offers TV & Radio
2	Responds to simple control commands from within or outside the home	• Unlock/lock door • Check for doors/windows to be open/locked • Turns on lights • Checks for mail • Gets help in case of a problem (fall)
3	Automates household functions	• Regulates temperature, humidity • Turns on/off lights/alarm sensors/music/TV at predetermined times
4	Tracks location in the home, tracks behaviors, and/or tracks health indicators	• Determines activity/sleep patterns, health status
5	Analyzes data, makes decisions, takes actions	• Issues alarms / provides reports (to residents, distant care giver or formal service provider • Makes changes to automated functions based on learned preferences (temperature, lights, music)
6	Provides information, reminders, and prompts for basic daily tasks	• Notified when mail has arrived, someone is at the door, stove is left on • Medication, hydration, meal reminders • Task prompting (washing, dressing exercising)
7	Answers questions	• Orientation (time, day) • Scheduled visits • General information (Google) • Have I …. (taken medication, exercised)
8	Makes household arrangements	• Schedules maintenance and repair visits • Order medications, groceries • Preparing meals • Cleans the house

Table 1: complexity-levels of smart assistive technologies (Mann et al., 2005)

Level 1 technology relates to communication, providing "residents with the means to communicate with and receive communications from others beyond the home" (Mann et al., 2005, p. 34). Telephones (both mobile and fixed) probably represent the best-known example of a level 1 technology, but also the so called 'super phones' in which traditional voice communication is combined with internet access for web browsing and e-mail, a digital camera, an MP3-player, contact lists, schedulers et cetera are examples of technologies that are assigned to this level. Level 1 technology is currently available in almost all European countries and even already present in many European households. Internet access, and particularly high-speed internet access, is crucial for optimal use of smart homes. The good availability of such internet access in Europe makes the creation of smart homes potentially very successful (Mann et al., 2005).

Level 2 technology typically refers to technologies that enable electrically powered applications in the house being operated without the use of a switch or control button attached to or wired into the application. Examples of these technologies include door-locks with an electronic mechanism to set the bolt, lights, thermostats, and mechanically controlled windows and curtains. Although most systems currently on the market use a remote control similar to a TV remote, ideally these systems respond to voice commands (Mann et al., 2005).

Level 3 technologies relate mainly to devices that control the temperature and/or humidity of a room. These technologies are often seen in commercial buildings, but household usage increases. In addition, other devices could be automated, like when the lights should turn on/off, or when the television should be turned on. Computer-based smart home products allow more flexibility and features in this level of automation, like different scenario's (weekends versus weekdays) (Mann et al., 2005).

Technologies assigned to Level 4 provide the ability to locate a person in their house, so it can take appropriate actions in the specific location of that person. If the home 'knows' were a person is, it can for example issue reminders or alerts at the location of the resident, but it also can track behaviors such as trips to the bathroom, visits to the kitchen, turning in bed, time spend sleeping/sitting/eating et cetera. Tracking health indicators take measurements of vital signs and weight (Mann et al., 2005).

While level 4 technologies can already gather data, it does not really adapt its actions based on an analyses of these data. Level 5 technologies do recognize for example when residents deviate from typical patterns, like skipping meals or losing too much weight. Based on these observations of the home itself, it could alert the resident, caregiver, or a family member, to check if the person is well. Additionally, the house could be capable of compiling health status reports on a daily base, which makes it easier to determine deviations from normal behavior or routine (Mann et al., 2005).

Level 6 technology is particularly useful for someone with cognitive impairment, which makes it difficult for him/her to remember daily tasks like dressing. Technologies from this level will 'know' when mail is delivered, when the stove has been left on too long, or when a resident has forgotten his medication. When it notices deviations from normal practices, the smart home will prompt the resident with voice and/or visual clues to the appropriate action (Mann et al., 2005).

Level 7 technologies gives residents the ability to question their house about their historical actions (like if resident has taken its medicine today). Additionally, residents can 'ask' their house questions not answerable by the historical data gathered by the house, but based on information on the World Wide Web. Ideally, this is based on a voice recognition interface, which enables both voice-input of questions and voice-output of the answers.

Finally, level 8 technologies will create a fully independent system, determining the needs of a household (like groceries, medication, broken equipment), and taking detailed appropriate actions (like seeking input from the resident for the menu for the next few days, preparing a grocery list, ordering groceries, and arranging delivery). Although this level sounds still futuristic, technically it is to a large extend already possible (Mann et al., 2005).

Although previous classification of levels of complexity is arbitrary[1], it is a very detailed one, which makes it particularly appropriate for explorative research (Schuurman et al., 2007). The description of different levels of smart technologies will enable a classification of the cases identified for this research. Additionally, this

[1] Philips has created another classification of five different levels of complexity (embedded, context aware, personalization, anticipation, and adaptation) (Wehrens, 2007), which roughly correspond to level 3, 4, 5 & 8 of Mann et al. (2005).

research will search for similarities within cases of similar levels of complexity, in terms of user involvement, current types of user representation and ideal types of user representation.

3.2.1 Underlying technologies

As technologies related to smart homes and/or to smart ATs are numerous, it is impossible to discuss them all. Therefore, this section will only discuss the most important ones (Dewsbury, 2009; Mann et al., 2005), which enables better understanding of the product- and technology descriptions of the cases.

Sensors

Sensors are the key features of a smart home and are able to detect temperature, moisture, movement, light, sound, acceleration, odors, and much more. Information that is gathered by the sensors is sent to a storage/analysis unit (computer), often referred to as a platform. From this platform, information can be sent to care givers, relatives, or other organizations. Many sensors already exist, and when the concept of smart homes will further develop, even more will be developed. The following sensors are the most common ones used and most relevant to discuss for this research:

- Environmental sensors: relate to sensors placed around in the house (on or under furniture, floors, walls), regardless their function. Downside of these kinds of sensors can be that they cannot determine who is being monitored.
  - Passive infrared sensors: are environmental sensors aimed at tracking movement of people.
  - Fiber-optic floor vibration sensors: environmental sensors measuring movement, but additionally measuring step count, cadence, pace, step duration, and determining normal gait, limping, or shuffling gait. This sensor can also detect falls and works on carpeted, concrete and wooden floors. Data obtained by this sensor can be wirelessly transmitted.
- Personal, wearable sensors: these sensors can be attached to jewelry (such as rings, pendants or watches) or directly to the body. Advantage of this sensor is that it can gather more-basic physiological data. However, they have more limitations than environmental sensors: need for power, need for great durability, risk of being uncomfortable/intrusive/unsightly, and risk of misuse.
  - Kinematic sensor: attached to a person’s chest it can detect different body postures (lying, sitting, standing.

Computers, software & the internet

As already mentioned above, sensors gather information and sent this information to a computer, which subsequently sent this information to the residents itself and/or to external caregivers. However, in most cases it is not very practical when this computer sends all available information ‘raw’, without processing it first, because not all information requires an action. Therefore, software is needed to “digest” the data and to send reports on request and/or alarms in case of an emergency. Communication of residents with their smart house and smart products needs additional software, which preferably is based on voice recognition. The internet could provide a pathway for messages and reports, as well as being a source of information and services to the home.

User input & output devices

Basic input devices are a keyboard and a mouse or touch screens, but in the future, this will be replaced by smart phones or voice commands software, which requires microphone arrays placed around the house. The major output channels of smart homes will be video and audio devices, such as (flat screen) monitors and speakers. When residents are not at home, output will be through their smart phones (both visual and auditory).

Mechanical hardware

Devices like door locks, automatic window openers/closers, and automatic shades and drapes openers, require mechanical systems. Although these systems are already available for several years, they can now be integrated into the smart home concept, enabling residents to monitor and control them through the input devices of their smart home.

Wireless technology

Wireless technology enables invisible connections and communications between devices. An obvious advantage of wireless connections is the elimination of the need to have a cable or wire between devices (enabling higher levels of mobility). However, wireless devices require power, which is usually provided by batteries that have a limited life between replacement or recharge. In the past, most devices communicated through X10 technology, which uses household AC power lines to transmit messages. As X10 technology only enables communication in one-way, it was not possible to observe the consequences of certain actions or problems. When, for example, a light was asked to turn on while the light bulb was broken, the computer was not able to observe this and take appropriate actions. Better suitable wireless technology is the technology used for mobile phones. This technology continues to advance through different generations (2G(GSM), 2.5G(GPRS) 3G(UMTS), 4G), with improving data rates and additional capabilities. WAP (Wireless Application Protocol)-technology provides a “world standard to reformat content of internet communications to fit the display screen of wireless device(s), … providing internet communications and advanced telephony services to digital phones and other wireless terminals” (Mann et al., 2005, p. 45). This standard was very important in the development of wireless services. ‘Small area wireless technology’ like Bluetooth and 802.11[1] are two very similar technologies that enable additional wireless communication but are limited to short-ranges. The data-transmission speed of both improved over the past, and currently Bluetooth even uses 802.11 technologies because it is faster and more reliable.

Power line communication networking

When sensors are not wireless, they are usually connected through the grid. In that case, technical advances have made it possible for communication to take place through the power lines.

Smart appliances and products

As products get smarter, they can be incorporated in the smart home concept, which enables people to monitor and control them through the smart homes’ interfaces. Moreover, when software improves, the smart homes’ computer (platform, analysis unit) will be able to warn residents when appliances need maintenance or form a thread to residents’ well-being.

Feature & object recognition, GPS

This camera-type device can be used to scan persons’ faces and match them to an existing database, enabling identification when for example ringing the doorbell. This technology is important for improving security. Object recognition technology recognizes objects like furniture or appliances and monitors their movement within a house. These are not suitable for person tracking, as they are much slower. GPS (Global Positioning System) enables locating people outside their homes.

Digital ID

Digital ID is based on RFID (Radio Frequency Identification) or the transmission of signals between information stored on a ‘smart tag’ and a ‘reader’. Using this technology does not require direct contact with the reader (as magnetic strip technology does), nor a direct line of sight with a reader (as bar code technology does). The so called ‘smart tags’ contain memory and a dormant memory emitter, which is charged enough when beamed, sends its memory content to the reader.

[1] 802.11 technology (or more specifically the 802.11b technology) is more commonly known as Wi-Fi.

4 Research design

As mentioned in the introduction, theories about user-producer interactions in the form of consumer-producer interactions, and the knowledge available in the addressed research field, are underdeveloped (Lacey & MacNamara, 2000). Nevertheless, chapter 2 has not only propounded the importance of user-involvement in the development of smart ATs and the expected relation between the phenomenon of user involvement and the contextual conditions within firms (which rectifies the explorative character of this research (Yin, 2003)), but also the existing tensions in literature. The tensions this research aims to elucidate are, how users are actually defined by developers (sub research question 1), and how and when (and why) users are currently considered or involved in development processes (sub research question 2) of smart ATs in The Netherlands. These two questions are of an explorative nature, because they aim at determining what sources of use information are consulted by developers of smart ATs in The Netherlands and which users are relevant to consider, according to the developers. Sub research question 3 (and partly sub research question 2) has an explanatory character, because they aim at determining a motivation why developers have consulted specific sources of use information. Is it because they are hampered to consult other sources (e.g. because of a lack of financial or human resources), or do they consider these sources to be sufficient or even best available? The field of smart ATs was not only selected because of the urgent societal need for independence enhancing products, but also because of the radical character of innovations in the field, which makes development processes more demanding and risky, and increases the necessity of developers to (in some form) consider or involve users.

This research started with a close examination of available scientific literature about the importance of user-involvement in innovative projects in general (e.g. Lettl, 2007; Peine, 2007; Woolgar, 1991; Hippel, 1988) and in the development of smart ATs in particular (e.g. Fisk et al., 2009; Iivari, 2006; Mann et al., 2005; Kujala, 2003). This assisted in formulating the research questions of this research, clarified the relevance (both societal and theoretical), depicted the important considerations about smart ATs and user-involvement, and helped to define the boundaries of this research.

Because of both the explorative and explanatory character of this research, and the theoretical underdeveloped issues at stake, a multiple case-study research method was selected as the most appropriate one (Yin, 2003). This multiple case-study design allowed researcher to explore the phenomena under study (i.e. the applied sources of use information), by first applying a literal replication strategy, in which cases were selected to obtain similar results. Subsequently, a theoretical replication strategy was applied, in which cases were selected to explore and confirm or disprove the patterns identified during the initial stage (Zach, 2006; Yin, 2003). This research method provided me with the opportunity to determine ('measure') which users are considered relevant, which sources of use information are consulted, and why developers selected these sources. Moreover, because of the exigency for qualitative and relatively deep data to 'measure' these, researcher conducted interviews. The multiple case-study research method additionally provided researcher with the opportunity to alter (obviously within certain limits) research design during the data gathering process and to obtain as much information about and insight in the various forms of user involvement in development processes of smart ATs. A description of alterations made for this research is discussed in section 2.4, which would not have been possible in more rigid research methods.

4.1 Case selection

The unit of analysis of this research is a development process of a smart assistive technology, which is mostly initiated by firms. In order to be able to gather information about these development processes, I therefore started selecting firms involved in smart AT development processes, based on the following criteria:

- Firms must be involved in the design and/or development of some sort of smart assistive technology
- Design- and/or development processes must take place within The Netherlands[1]
- Firms must have some level of influence on the design- and developing process themselves.

Assisted by the Dutch foundation 'Stichting Smart Homes', a first selection of firms was made. However, not only firms that initiate an innovative development process influence a development process. Often, innovation projects include all sorts of external parties as well, in order to have additional knowledge sources about technical issues, user issues and much more. Because of this reason, I have not selected firms as the unit of analysis, but innovation processes in its most comprehensive form. This enabled me not only to interview developers of the firms that initiated the development process, but also (if possible, present and relevant) other companies, institutes et cetera, that had some influence in the development process. To give an example from the selection of cases for this research: in the Amido-case, I did not only interview developers from Ascom (Nederland) B.V., which is the initiating company (with experience in the professional healthcare sector). I Also interviewed developers from Alphatronics B.V. (which was responsible for the security aspects of the Amido), and developers from Daza Opticare B.V. (which was responsible for the home care aspects of the Amido). Hence, I was able to determine what each of the key-players considered as a potential user and which sources of use information they currently consult and would ideally consult. Cases could not only be built up out of multiple firms (as in the Amido-case), but also out of other entities like pharmacists, doctors, care institutes et cetera. Figure 3 gives an overview of entities that could be involved in the innovation processes and thus could introduce use information into the innovation process, which is the focus of this research. With interviewees it was determined if any of them are relevant to consider for this research.

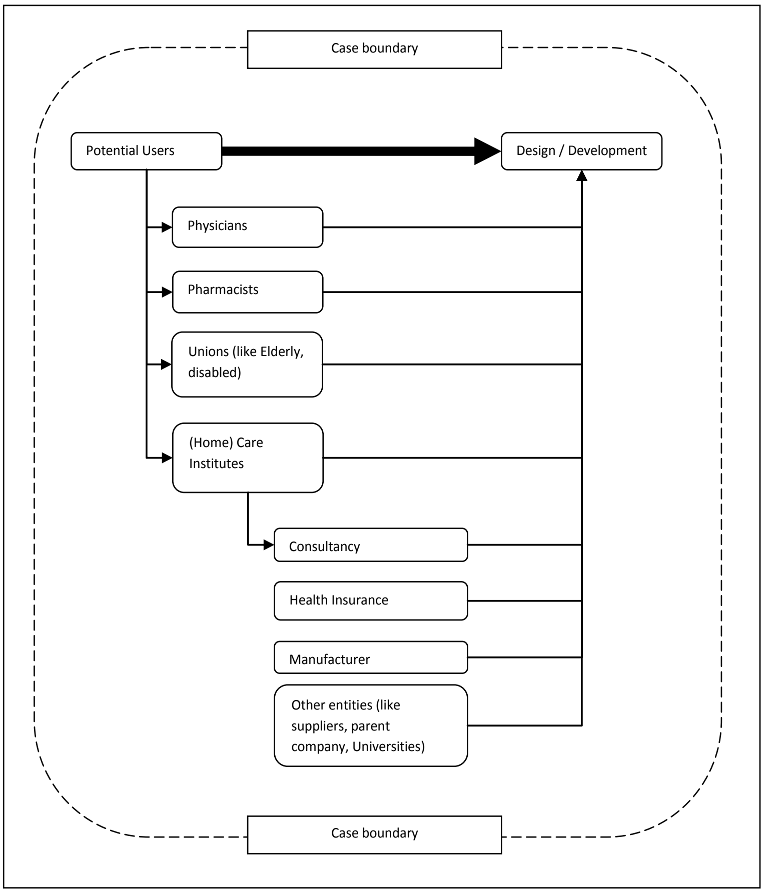

Figure 3: Case boundary

[1] Limiting this research to firms within The Netherlands is mainly because of time- and resource constraints.

4.2 Data collection

After selecting appropriate firms, I (in colloquy with the firm) selected one innovation project (i.e. design- and development processes) of a smart AT this firm was involved in (or initiated), and carried out interviews with people involved in this project. Cases (innovation projects) (Appendix A) had to meet the following criterion:

- They must design and develop at least one smart assistive technology, according to the criteria mentioned in chapter 3.

Whenever possible, two or more interviews per case were carried out to increase construct validity[1] (Yin, 2003), although this turned out to be very difficult in smaller cases, when often only one firm or even one person was responsible for design and development. In these cases, the insights gained from single interviews were considered equally valid as those gained from multiple interviews. All interviews were digitally recorded, transcribed, categorized, summarized, and subsequently reviewed by interviewee, to enhance construct validity even more (Yin, 2003). Letting the interview summaries being reviewed by the interviewees enabled interviewee to confirm the data, to add data when necessary, and to censor confidential data. If a case had multiple interviewees, the succeeding interviews were used to confirm the data obtained from the first interview, or to determine deviations from it. The questions asked during these interviews were focused on the products under development and the applied sources of use information as discussed in chapter 2, and were split-up into the following sections: company information, product smartness & assistiveness, user-involvement (which, how, and when), design consequences of user-involvement, and interviewee's ideal design process with its constraints (Appendix B). For each case the interview summaries (reviewed and approved by interviewees), together with all written material obtained from either firms or through the internet, were subsequently combined into one case-summary, which was used as data for this research (Appendix C).

4.3 Data analysis

After the data gathering phase (i.e. interviewing and summarizing the interviews), the cases were aggregated into case-groups and described, including information about their mutual characteristics related to case-products' technological complexity and functionalities, and age and size of the initiating companies (see chapter 5). However, this aggregation was not pre-determined, but resulted from the technical complexity levels of currently available smart AT-products' innovation processes in The Netherlands. Moreover, case-products within these case-groups turned out to have similar functionality, namely tracking, tracing and alarm making (TTA), platform technologies and domotics (P&D), and smart medical equipment (SME), which are the names used to address specific case-groups. Cases discussed within this subdivision do not only share levels of complexity, but also functionality, which avoids discussions about individual allocations to the different levels of complexity. The analysis of all case summaries resulted in the table depicted in appendix D, which are graphically presented and discussed in chapter 5. To construct Appendix D, the following code-system has been applied (table 2):

[1] Construct validity refers to the degree to which illations can legitimately be made from the operationalizations in a study, to the theoretical constructs on which those operationalizations are based (Trochim, 2006; Yin, 2003).

Criteria	Dimension	Indicator
1. Size of initiator/owner of the development process	1, 2, 3	1 = initiator/owner has 6 or less employees 2 = initiator/owner has between 7 and 25 employees 3 = initiator/owner has over 25 employees
2. Considering only older adults important	0, 1	0 = no 1 = yes
3. Considering both younger and older adults important	0, 1	0 = no 1 = yes
4. Considering informal caregivers important	0, 1	0 = no 1 = yes
5. Considering formal caregivers important	0, 1	0 = no 1 = yes
6. Non- & implicit representation (current and ideal)	0, 1	0 = no 1 = yes
7. Involvement of ordering customer (current and ideal)	0, 1	0 = no 1 = yes
8. Direct & indirect representation after prototyping (current and ideal)	0, 1	0 = no 1 = yes
9. User participation after prototyping (current and ideal)	0, 1	0 = no 1 = yes
10. Direct & indirect representation before prototyping (current and ideal)	0, 1	0 = no 1 = yes
11. User participation before prototyping (current and ideal)	0, 1	0 = no 1 = yes

Table 2: operationalisation scheme

Criterion 1 is used for the general description of the case-groups (chapter 5.1). Criteria 2-5 all relate to sub question 1: which potential users of smart ATs are considered during its development process. Criterion 2 is valued 1, when developers only consider older adults during the innovation process, as when developers used specific standards/norms for products suitable for older adults. If they considered also younger adults, criterion 2 is valued 0 and criterion 3 is valued 1. More challenging was valuing criteria 4 & 5: involvement of informal- and/or professional caregivers. These criteria were valued 1 when, for example, developers either consulted them extensively (i.e. not only ones) or investigated their needs and wishes. Criteria 6-11 were determined by following the model described in chapter 2.4 and depicted in figure 2.

Besides this rather quantitative approach of the data, determining which users were considered and which sources of use information were (and would ideally be) applied, the data were also analyzed qualitatively. Interview summaries were consulted to retrieve information on motivations why developers consider either only end-users or also ‘additional’ users, and on why they consider only older adults or also younger adults as end-users. In addition, this qualitative analysis of the data provided a much more thorough understanding not only on developers’ motivations for applying the various types of sources of use information, but also on the intrinsic characteristics of the various sources of use information.

5 Results

This chapter starts with a description of the pre-defined case-groups in section 5.1, and analyzes the case-groups in section 5.2.

5.1 Case-group descriptions

This section gives a description of each case-group (TTA, P&D & SMD), defined by the use of common complexity levels (as explained in chapter 3) and their mutual functionalities, in order of increasing technological complexity.

5.1.1 Track, trace and alarm devices (TTA)

Within the TTA case-group, seven interviewees from seven different companies/organizations provided the data about the following seven cases (Table 3)[1]:

Case name (short)	Case name (full)	Company-names
CSV 1201/02	CSV 1201 & CSV 1202	Casev Optical Services TrackJack B.V.
Homesafety	Homesafety Alarm Systems	Essential Domestique Service B.V. - Homesafety
My-SOS	My-SOS	My-Bodyguard B.V.
Optipager	Optipager	DAZA Opticare B.V.
Quogle	Quogle	Quogle B.V.
Secufone	Secufone	Secufone B.V.
TrackJack	TrackJack Basic Edition	TrackJack B.V.

Table 3: TTA-cases

All mentioned companies involved in developing TTAs were founded in the last fifteen years, and most of them even in the last five years. This is probably the main reason why the companies initiating and currently owning the innovation process (the unit of analysis) are either small or medium sized. One case focuses on the sole development of hardware, two develop both hard- and software, but the majority acquires its hardware externally (mostly in Asian countries) and only develops software and additional services. None of the cases is involved in the entire chain of developing hardware, software and additional services. Technically, the case-products have in common their level of complexity (level 2), as explained in chapter 3, and their function: to give users a feeling of safety by enabling them to make an alarm by pushing an alarm button on a portable device. Traditionally, these devices are used inside users' own homes, but these TTA-devices are also developed specifically for outside use, or both outside and inside any building. In latter cases, the devices are supplemented with GPS-technology that enables the responder of the alarm to trace the alarm-maker. Three case-products send these coordinates unprocessed (i.e. as raw coordinates), which are only meaningful if they are looked-up in web-applications like GoogleMaps (www.googlemaps.com), and two case-products have developed software able to deliver not only coordinates, but also the specific location to the responder of the alarm-maker. The responders of the alarm can be relatives or non-professional caregivers, professionals (caregiver or alarm center) or both, depending on the user's requirements. Of the five case-products developed for outside use, four have the possibility of communication between alarm-maker and responder, and in one case, only the responder is able to hear what is happening at the location of the alarm-maker.

[1] Note that one company, TrackJack B.V., is involved in the development of two different cases.

5.1.2 Platforms and domotics (P&D)

Within the P&D case-group, thirteen interviewees from eleven different companies/organizations provided the data of the following seven cases (Table 4):

Case name (short)	Case name (full)	Company-names
Amido	Amido	Ascom (Nederland) B.V. Daza Opticare B.V. Alphatronics B.V.
HCB	Home Control Box	Home Automation Europe B.V.
iDAP & VHT	iDAP & VHT	CPS Europe B.V.
IRS 5G	IRS 5G	Niko Group N.V. - Fifthplay N.V. & IRS B.V.
Unicare	Unicare	CLB Benelux B.V.
VieDome	VieDome	Mextal B.V.
VSS	Verkerk Service Systemen	Verkerk Groep B.V. - Verkerk Service Systemen MVAVD Design

Table 4: P&D cases

Except for one case, all cases are initiated by companies that are over fifteen years old. However, all companies only recently started developing technologies for smart assistive products. The majority of initiating companies in this case-group is large or medium sized, which could be explained by the fact that most companies are relatively old. Technically, the case-products in this case-group have in common their level of complexity (level 5), as explained in chapter 3, and their functionality of being a platform or a combination of a platform with attached sensors and/or domotics. Platforms are essentially a switchboard between input coming from users or sensors and output either going to external parties or to devices in users' environment/home (domotics). Examples of input of users can be requests for services, alarms or controlling devices (domotics). Sensors can be used to trigger alarms (smoke detectors, trespassing sensors) or to provide data about all kinds of issues like health and well-being. Examples of 'medical' sensors are discussed in the following case-group of SMDs. When the output is internally, user will get response (for example a window shuts), or will get advice on for example health and well-being issues. However, the platforms can also communicate with external parties, which could for example be service providers like shops or professional caregivers. In turn, these external parties can provide feedback to the users through the platform again, making it also a communication device. All platforms can be operated either by the use of mechanical buttons, or by the use of a touch screen. The cases focusing only on the development of platforms are also the cases that are initiated by the youngest companies. Although one case develops specifically for extramural settings, most cases focus on providing users in both intra- and extramural settings, which is not striking because these cases are initiated by relatively older companies, which were already active in the intramural sector before the growing need for extramural solutions.

5.1.3 Smart medical equipment (SMD)

Within the SMD case-group, seven interviewees from five different companies/organizations provided the data about the following four cases (Table 5):

Case name (short)	Case name (full)	Company-names
CC	Connected Care	Koninklijke Philips Electronics B.V. - Philips Design
Medido	Medido Connected	Innospense B.V.
RTMM	Real Time Medication Monitoring	Evalan B.V. Inspiro B.V.
SmartBlister	SmartBlister	Koninklijke DSM N.V., - The Compliers Group International B.V.

Table 5: SMD cases

Companies initiating the development of these case-products are in general very young, although one was recently acquired by another old and very large company. Only one case is initiated by an older company, although it did not become clear to me if this company had developed the case from the start or acquired the technology externally. The lack of more cases in this group can be explained by its high level of technical complexity (level 6) as explained in chapter 3, and its high novelty factor. All case-products have in common that they aim at improving therapy compliance, health, and well-being by warning users through a device or by text messaging to a user's cell phone. Warnings to users are given when users have to take medication or other appropriate health actions, and/or when users fail to take their medication. Ultimately, a warning to (professional) caregivers is given, when after have been alerted, a user still does not take his/her medication or when user's health is at risk. Two case-products make use of a physical artifact where medication has to be stored in, while one applies technology to existing medication packaging. The latter case-product is not on the market yet. The fourth case develops products that assist people in maintaining a healthy living, by measuring health-indicators and providing users with useful feedback. Subsequently, all cases make use of a database that stores the actual moment when medication is taken or when health-indicators are measured, compares these data with when medication should have been taken or when health-indicators exceed certain pre-set values, sends warnings to users and ultimately warns (professional or informal) caregivers.

5.2 Case-group analysis

This chapter discusses and explains the results of this research per case-group, following the sub-research questions as depicted in chapter 1. Preceding the analysis of the results, I can already indicate that obviously, all development processes consult at least one source of use information, because of the broadness of the definition of user involvement. Differences occur in how the cases define their potential users, how these users are currently represented, and how (according to interviewees) users can/should ideally be represented. The consideration of specific potential user groups, is grouped into two categories: end-users (divided into considering only older adults, or both older and younger adults) and additional users. None of the cases only considers younger adults as potential end-users, which is not surprising when considering the focus of this research on assistive technologies.

5.2.1 Track, trace and alarm devices (TTA)

5.2.1.1 Which (potential) users are considered?

As figure 4 shows, over 70% of the TTA-case-products are developed specifically for older adults, while little under 30% consider also younger adults. Considering the functionality of the devices (as described in section 5.1.1), it is not surprising that the majority of these products are specifically developed for older adults. Older adults are more likely to feel unsafe, because of their emerging physical and/or mental limitations, which explains why many developers focus specifically on them. Cases that consider both younger and older adults differ from other cases in that their product on the one hand is related to general home safety systems, and on the other is actually developed specifically for a broader potential market, in terms of functionality and design. Additional users are virtually never considered, except for one case which considers end-suers as well as informal- and professional caregivers.

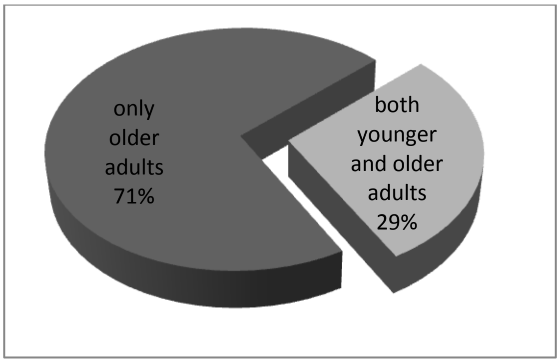

Figure 4: For what age group developed (TTA-cases)

Interview summaries also show that developers of TTA-cases would consult users (direct or indirect) when either the product is new for the user (in its broadest sense), and/or the users are new for the company. When functionalities are already known by users (like mobile phone technology in TTA-cases), developers copy the characteristics of these products in such a way that operating characteristics remain similar and use-problems are unlikely. When a company is experienced in developing products for one kind of users (e.g. younger adults), and additionally wants to serve other users (e.g. older adults), they are more likely to have direct or indirect consultation of these (for the company) new users, than when a company makes a new product for company-familiar user groups.

5.2.1.2 When is which source of use information consulted?

Figure 5 shows that all TTA-cases apply the same source of use information during the development of their products; all rely on non- & implicit user representation. In none of the cases, one could speak of an external party ordering a TTA-product, and it did not occur that experts, mediators, or (potential) end-users acted as source of use information, either before or after prototyping. Reasons why users within the TTA-cases are represented non- or implicitly are not unambiguous. Some interviewees mentioned the importance of technical aspects of the products as the main reason why the source of use information was more to the manufacturer side and less to the user side of the continuum. Other interviewees mentioned a lack of financial resources as explanation. However, interviewees' experience with older adults in former employment is given as main reason why users were not represented through one of the other types of user involvement. The similarities of the TTA-products with products already used by older adults are addition reasons why end-users are not specifically involved. TTA-products are in essence a personal alarm device in combination with a cell phone with limited functionalities, both already known to many older adults. As TTA-products are technologically not very complex, and rather entail a new combination of already proven technologies, it is perhaps less important for developers to consult more intense forms of user involvement.

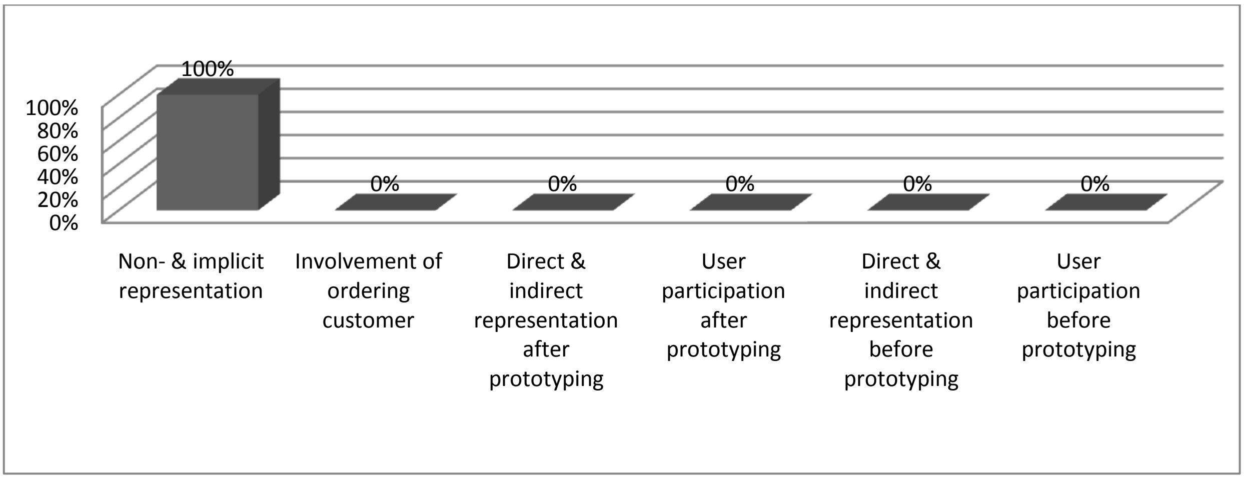

Figure 5: Current user representation (TTA-cases)

Detailed analysis of the interview summaries also show that interviewees mainly consider specific and concrete market requests to be the correct rationale for starting a development process, which is also an explanation for the relatively low applied intensity levels of user involvement. If a current developer for many years experienced or observed a problem during his working life, he already gained so much insight on (potential) use, that consulting users (directly or indirectly) would not necessarily provide him with additional insight. In such case, one could almost speak about user participation before prototyping (or one of the other higher intensities of user involvement); though with the participation/consultation of users taking place several years before the actual start of the development process.

5.2.1.3 When would which source of use information ideally be consulted?

Figure 6 not only shows what the sources of use information currently are in TTA-cases, but also what (according to interviewees) the most ideal sources of use information in the development of TTA-products are. In 71% of the TTA-cases, interviewees would have preferred to have direct & indirect representation after prototyping and user participation after prototyping as additional sources of use information. End-users in this case would be involved in testing the prototypes, and experts or mediators would test whether the products would be helpful for adults they represent. Moreover, despite reasons given in the previous section, in 43% of the cases, interviewees consider direct & indirect user representation and user participation before prototyping to be helpful sources of use information. Figure 6 additionally shows a large discrepancy between current practice and ideal practice.

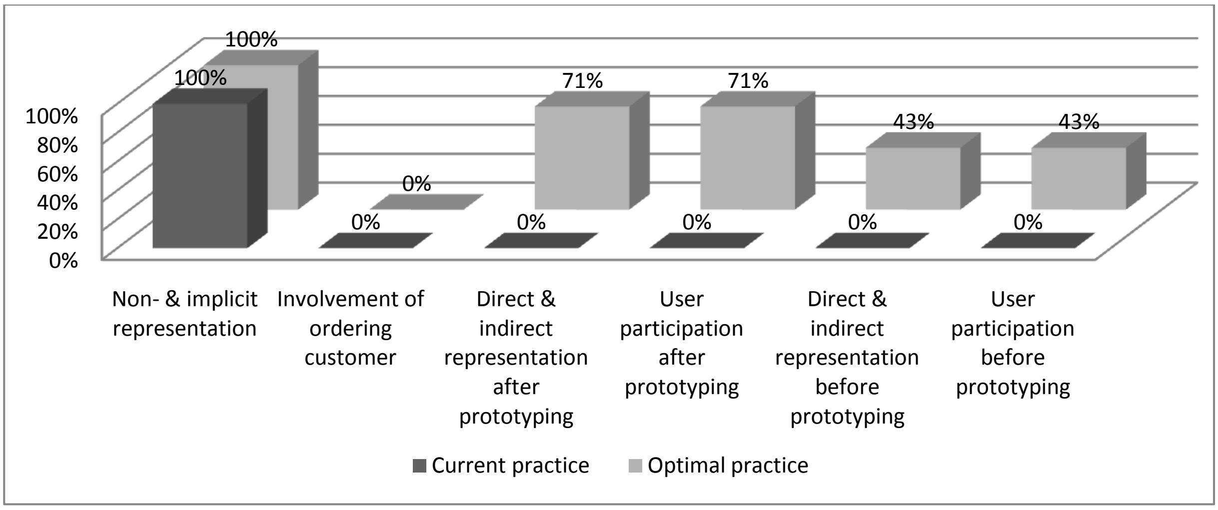

Figure 6: Current versus ideal user representation (TTA-cases)

A possible explanation as to why interviewees currently do not apply user participation as a source of use information is that developers expect difficulties when involving their (potential) users, because of users' mental and physical limitations. This makes developers hesitative in consulting them directly, either before or after prototyping. Older-adult-experts are not being involved as frequently as developers would have preferred, because these experts are thought to face major workloads from their jobs in the healthcare sector, which would hamper them in spending sufficient time on informing developers. Additionally, the occurrence of the most intense sources of use information is the lowest, because it is the belief of many interviewees that a prototype is a necessity to obtain useful information from either experts or potential users.

Analysis of the interview summaries additionally show that if companies apply lower intensities of user involvement during the development process and experienced resistance of users (in its broadest sense) during market launch, they are more likely to consider higher levels of intensity as their ideal sources of use information. Reasons in these cases given for not-applying higher intensities of user involvement are cost constraints and management pressure. Companies with lower levels of user involvement and without experiencing user-resistance (or companies that are not aware of user-resistance (yet)), are much more convinced of their applied non- & implicit user representation as their ideal sources of use information. Apparently, in this case-group, developers have to experience a hampering market launch, before they define higher intensities of user involvement as their ideal sources of use information.

5.2.2 Platforms and domotics (P&D)

5.2.2.1 Which (potential) users are considered?

The products & services of this case group not only aim to serve the specific needs of older adults, but also aim at general well-being, which is probably the main reason why developers within this case group are not only focused on older adults as their potential users (43%), but also on younger adults (57%) (Figure 7). Additionally, some of these platforms and domotics are used for high-end homes in which both older and younger adults live. This is another reason why developers focus on both younger and older adults as potential users. However, the historical background of the company that initiated the development process seems to be most important. When a company is already active in the healthcare market, it is more likely that it will remain focused on older adults as potential users and not consider younger adults as well. If a company historically focused its activities either on younger adults or on both older and younger adults as their potential user group, they are not likely to restrict themselves exclusively to developing smart ATs specifically for older adults. Considering potential users of P&D-cases, it is important to realize that the group of older adults in itself is not uniform. Within the group of older adults, users with either a direct need for care, living in protected housing, as well as those with privately owned housing can be distinguished. This non-uniformity also explains the focus of developers on potential users in the broadest sense, since technically classified 'older adults' sometimes have needs more comparable to those of younger adults.

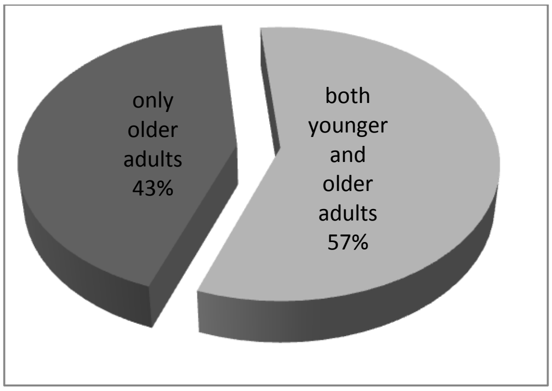

Figure 7: For what age group developed (P&D-cases)

As P&D-cases create a gateway or portal for end-users to obtain goods, services, et cetera, from anywhere in the world, it may be obvious that these case-products have many additional users besides end-users. Perhaps counter intuitively, this is the reason why none of the cases makes an effort in involving them. One interviewee even explicitly stated that it was a deliberate choice to involve only end-users and not any additional users. Obtaining too much input from either experts or additional users would have led to contradictory design requirements, would therefore not be useful for the developers, and unnecessary hamper the development process.

Close examination of the interview summaries of the P&D-cases additionally revealed that when end-user-experts are also additional users (for example professional caregivers), these experts have difficulties in separating own preferences from end-user preferences, which for many developers is a reason not to pay (too much) attention to these additional users. Moreover, paying attention to additional users is expected to take much time and effort, and developers expect that ordering customers already consider additional users sufficiently.

5.2.2.2 When is which source of use information consulted?

Figure 8 shows clearly that in all cases the ordering customer is used as main source of use information. 71% of the cases also apply non- & implicit user representation as source of use information, which means that two cases are developing P&D-products without relying on previous experiences or own preferences and skills. Just over half of the cases apply user participation after prototyping (mainly testing of prototypes) as source of use information, but some also apply direct and indirect user representation before prototyping. User participation before prototyping is never applied.

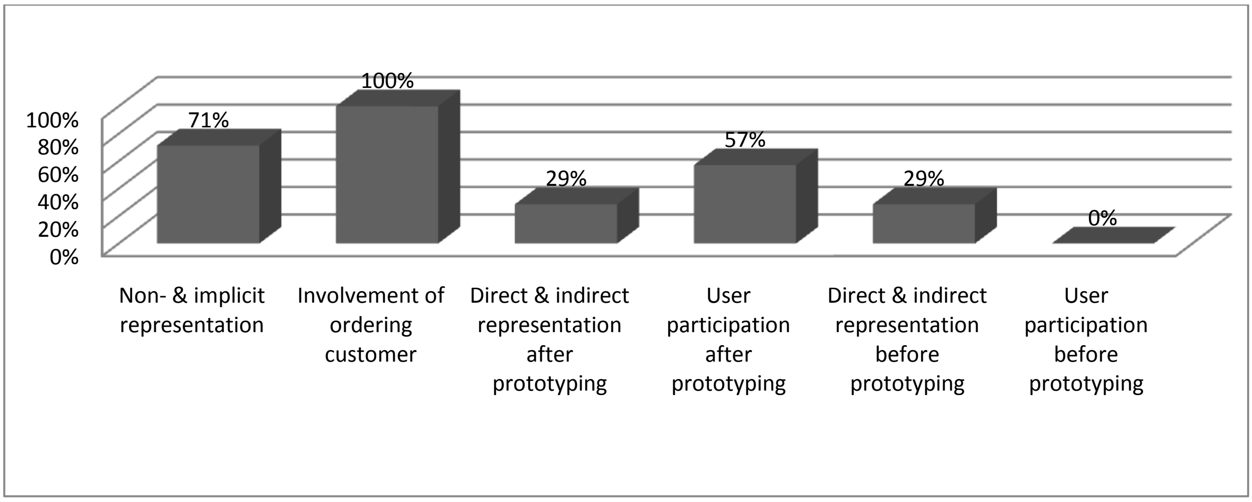

Figure 8: Current user representation (P&D-cases)

According to the interviewees, reasons why the sources of use information in the P&D cases have low intensities are that previous work-experience with end-users is sufficient and abundant, and/or technical issues are more important to focus on. In addition, developers see ordering customers (which are either building owners or managers of elderly- or nursing homes) as a very knowledgeable source of use information, which is the reason why they currently do not apply more intense levels of user involvement. On the other hand, developers realize that ordering customers have a larger interest for technical issues and less on user issues. This could make them less suitable as source of use information, though they may be practically impossible to neglect. Influence of ordering customers is not only persistent and unavoidable, but also present during the entire innovation process, which makes it so excessive, that other sources of use information are sometimes 'forgotten'.

Closer examination of the data reveals that, because P&D cases are mainly initiated by large companies, it is more likely that these companies have sufficient in-house knowledge about potential users. In this case, consultation of external experts is not necessary, because employees act as experts. This explains the relatively low percentages on direct & indirect representation both before and after prototyping (Figure 8). When a case only applies non- & implicit representation, this is not only based on former employments, but also on written sources about potential users and on insights obtained through sales departments. In some cases, this latter source is an important source of use information, though difficult to allocate, because it is usually not part of a development process but often acts as rationale that precedes the start of such process. Even more difficult to allocate are the informal consultations of potential users in developers' personal circle of acquaintances. This kind of user participation does not comply to definitions given by either innovation or design literature, but it does provide developers with information (though limited) about users. For this research, these consultations are not allocated to any form of user participation, but they can play an important role in the development process. Nevertheless, even with this form of user participation, developers stress the importance of having a prototype available for obtaining useful information about (potential) use. The slightly higher percentage of user participation after prototyping is explained by the presence of an ordering customer, who can easily test products at his/her (care-)facility. In addition, seminars and fairs are used to test prototypes among users (mainly additional users) although (according to interviewees) usefulness of this type of user participation after prototyping is doubtful.

5.2.2.3 When would which source of use information ideally be consulted?

A comparison of sources of use information currently used, and sources of use information that interviewees consider desirable for P&D cases is depicted in figure 9. From this, it becomes clear that all cases consider non- & implicit representation as well as ordering customers to be valuable as use information source. The majority of the cases additionally considers direct & indirect representation and user participation after prototyping valuable, and some consider direct & indirect representation before prototyping to be desirable. A minority would ideally let users participate in the development process before prototyping. Figure 9 additionally shows that the difference between current and ideal practice is not very large. The main discrepancy between current and ideal practice occurs in direct & indirect representation after prototyping. Reasons why developers do not apply direct & indirect representation after prototyping as source of use information could be that their main input is obtained from ordering customers, and that it is difficult to ask other parties about products which a firm developed for one specific customer. Ordering customers, most of the time, have a strong opinion about design and moreover pay for the specific development, so they are not easily disregarded. Nevertheless, developers would have liked to consult experts and/or users after prototyping, if they would have been able to, although interviewees stress that the background of experts has to be kept in mind. If experts have a technical background or are additional users, they will provide less relevant insights about end-users and more about technical possibilities or their own preferences as additional users (service engineer or caregiver). Both user participation and direct & indirect representation are, according to most interviewees, not favored before prototyping. Developers are of the opinion that a prototype is crucial for getting useful information from users, experts or mediators. In addition, developers are constrained by the available resources (financial and human), time, and knowledge to apply higher intensity levels of use information. If one would apply user participation before prototyping, this should be done in a highly structured way, which focuses on specific aspects, and not on creative aspects. One cannot expect users to define problems and come up with useful solutions.

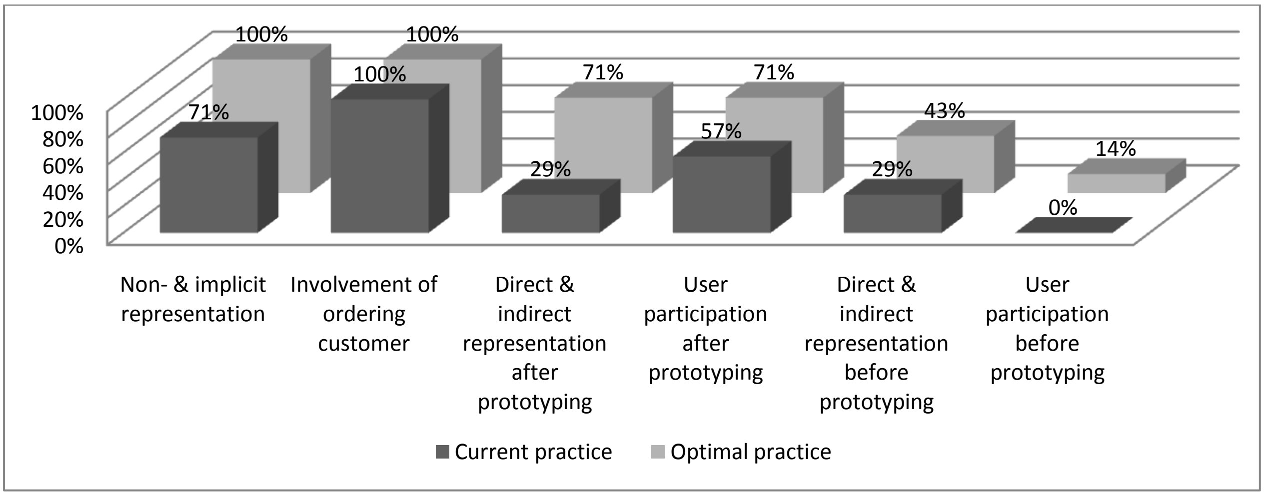

Figure 9: Current versus ideal user representation (P&D-cases)

5.2.3 Smart medical equipment (SMD)

5.2.3.1 Which (potential) users are considered?

Figure 10 shows that 75% of the case-products are developed for both younger and older adults, which has several reasons. The first one is that 'problems with therapy compliance' is something both older and younger adults face. Generally, older adults more often use medication, but when younger adults have to take medication frequently, it is less of a routine and therefore possibly more difficult to adhere to. These smart medication devices can therefore be very helpful for both age groups. Sensors that track health indicators can not only measure values like blood pressure and weight, but can also assist people in complying with a healthy lifestyle, which are functionalities that involve both older and younger adults. An additional reason why developers focus mostly on both age groups is that professional caregivers are still resistant toward technologies that assist them in their provision of care towards their clients. This hampers the introduction of these devices in the care sector for older adults and forces cases (and companies) to shift their focus to a broader age group.

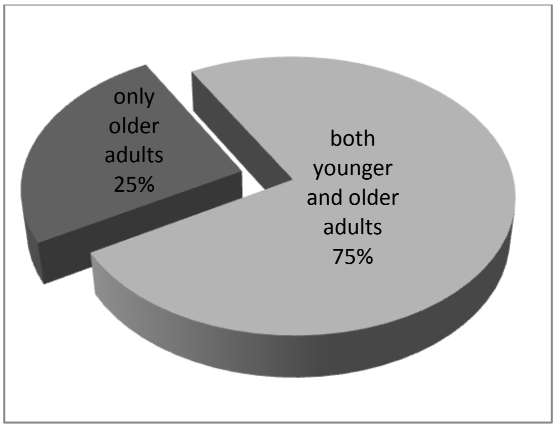

Figure 10: For what age group developed (SMD-cases)

Additional users are to a high extent considered during the development process of SMD-products. Healthcare professionals are considered as additional user, because they need to believe that the technology will provide them with accurate and reliable information that enhances their ability to provide care. In some cases, they also have to 'use' the SMD-products (or derivatives of it, like databases). Informal caregivers must feel that the technology offers them ways to support and care for their loved ones. Finally, insurance companies need to be convinced that the new business models that are a consequence of the technology are financially feasible and competitive in the economic climate of healthcare. The focus of developers on such a broad group of potential and additional users, forces them to develop 'container-solutions' which can be adapted to individual needs, rather than developing individual solutions.

5.2.3.2 When is which source of use information consulted?

Although not all cases apply own experiences as source of use information (75%), in all cases direct & indirect user representation after prototyping is applied as source of use information (Figure 11). 75% of the cases also apply user participation after prototyping, and 50% applies direct & indirect user representation before prototyping as source of use information. User participation before prototyping only occurs in 25% of the cases.

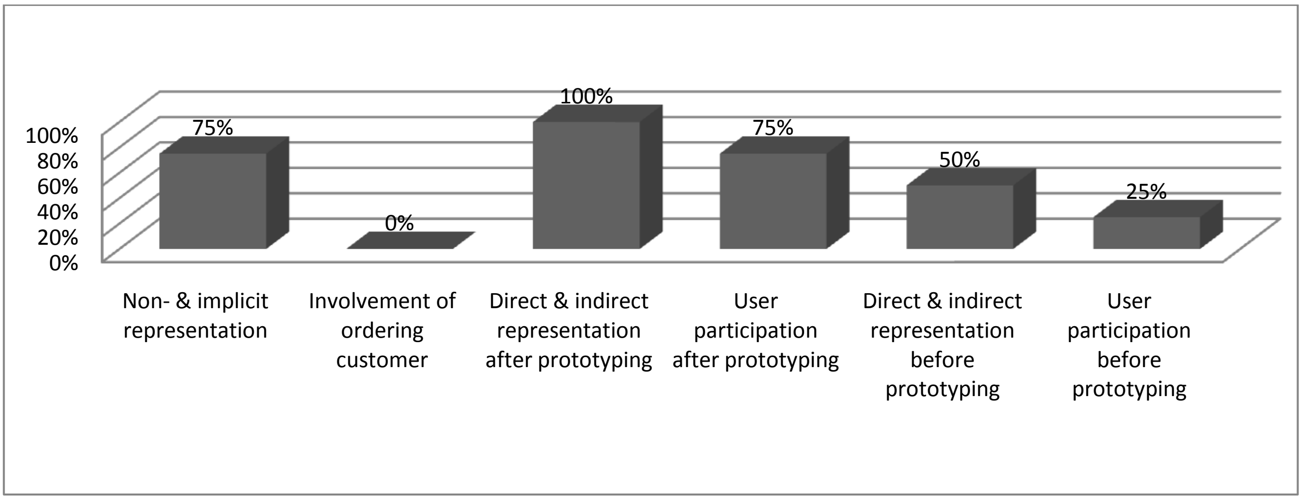

Figure 11: Current user representation (SMD-cases)

Reasons for the high occurrence of direct & indirect user representation as source of use information, both before and after prototyping, are the high novelty factor of the SMD-products (and with that the high risk of failure of the products to become a success), and the close links with healthcare issues. Products with a high novelty factor demand large investments, while it is not clear whether they will be profitable. Therefore, developers consult as many experts as possible to convince themselves and their financiers of the potential success of their products. The links with healthcare issues make it necessary to create very reliable products (also in the early market-stages), because people's health can be at risk and the consequences of product-failure can be substantial. Because the products are most likely to be prescribed by professional caregivers, they are also consulted in order to convince them about the usefulness of the products. The relatively high levels of intensity of the applied sources of use information can additionally be clarified by the fact that the majority of developers in this case group have a technical background (which is explained by the high complexity level of the technology), and are therefore forced to obtain information about use and users externally.

Non- & implicit representation occur either when developers have previous experience with the potential and/or additional users, or when companies are very large. In the latter case, they apply a multi-disciplinary development strategy, which brings people of multiple design and technology disciplines within the entire company together (like product designers, fashion designers, and communication & interaction designers). This allows them to learn together, in order to create a holistic experience of use across all aspects of the product. Direct & indirect representation after prototyping occurs when developers consult pharmacists and doctors and ask them to review a prototype. Direct & indirect representation before prototyping can occur in the form of stakeholder insight loops, which are used by developers to support and align the design and development process. They are carried out through interviews and observations with different consumer groups, a variety of medical professionals and insurance experts. When developers also apply user participation before prototyping (which only rarely occurred among SMD-cases examined during this research), they create a concept of 'personas'[1] (also referred to as user-image), which are fictional characters whose needs and values are determined from data gathered during interviews with people, making them representative of a typical user group.

[1] The concept of 'personas' is a specific develop-strategy of Philips Design

5.2.3.3 When would which source of use information ideally be consulted?

Figure 12 shows, that (according to interviewees) many SMD-cases prefer higher intensities of user involvement, compared to the sources they currently apply. Only user participation before prototyping is generally not considered useful, the main argument being that (potential) users are not able to give valuable information without a physical prototype. Other reasons for the discrepancy between current and ideal sources of use information is the novelty factor of technologies (which forces companies to focus first on making the technology work), and a lack of resources (which forces companies to put products on the market as fast as possible). Even in cases with already high intensities of user involvement, the novelty of this user-oriented or collaborative way of developing is fairly new, which means that it takes time to grow and settle as most optimal working practice in developers' daily jobs. When cases start with a 'working technology', they have a slight preference for lower intensities of applied sources of use information, compared to cases that start 'from scratch'. This can be explained by realizing that in cases starting with a working technology, the familiarity of developers with the technology (or product) is larger and therefore confidence about potential use is bigger.

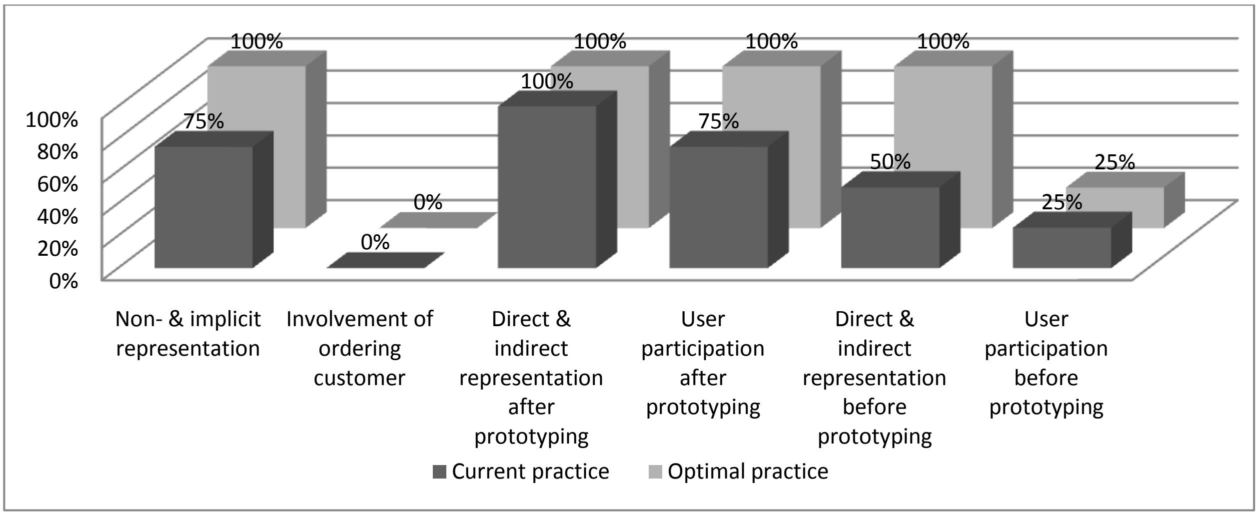

Figure 12: Current versus ideal user representation (SMD-cases)

5.2.4 Case-group comparison

When comparing the case-groups in terms of their applied sources of use information, it becomes clear that they differ considerably (Figure 13).

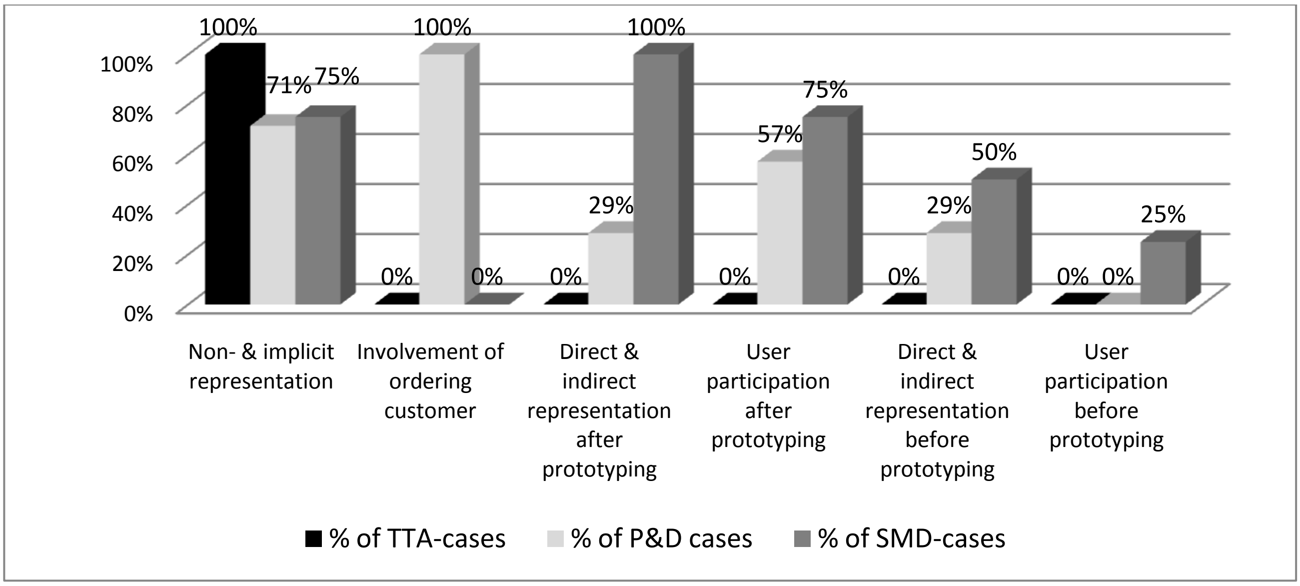

Figure 13: User representation per case-group

Cases developing products with a high complexity (SMD-cases) apply more intense sources of use information than less complex cases (P&D- and TTA-cases). Differences between current and ideal applied sources of use information in TTA-cases are most obvious, which means that developers of these cases are most hampered in applying the preferred sources of use information. When explaining this, it is important to consider that the majority of companies involved in the development process, and/or those initiating the development process are relatively small, sometimes employing only one or two developers. Figure 14 shows that relatively small companies apply lower intensities of sources of use information than large companies do.

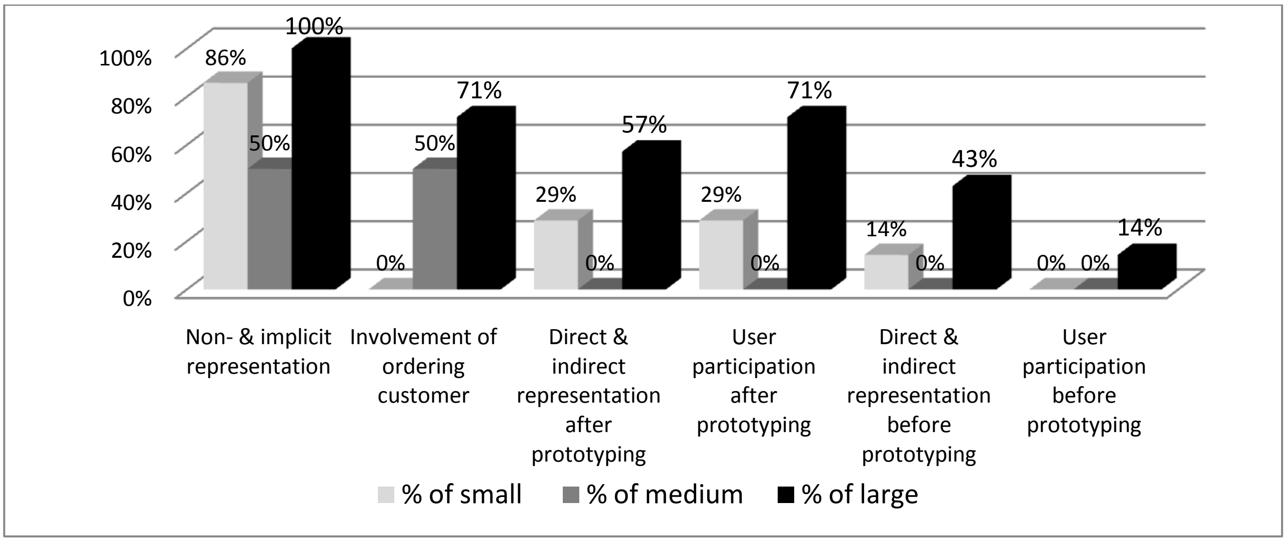

Figure 14: User representation per size-group

However, medium-sized companies that initiate and own development processes, apply even lower intensities of sources of use information. This is explained by the fact that the majority of cases initiated by medium companies are P&D-cases that are highly influenced and restricted by ordering customers. The main reason why large companies apply such high intensity levels of sources of use information is their access to substantially more resources (financial and human).

6 Discussion of empirical results and theoretical implications

This chapter discusses the two tensions that are presented in chapter 2 in relation to the results of this research as presented in chapter 5 and provides some theoretical implications.

6.1 Types of users

To recapitulate, the first discussed tension in chapter 2 was the difference between the more 'narrow' definition of users being only end-users as advocated by the practical design literature, and the 'broader' definition of users being also 'additional' users as advocated by the innovation literature.

Although all interviewees considered it important to define their potential users accurately, their definition has much dissimilarity. Fisk et al. (2009) and Mann et al. (2005) both consider older adults to be the most probable end-users of smart ATs, because older adults are most likely to benefit from the technologies. Nevertheless, in more than half of the cases, developers consider younger adults as potential users as well, because:

a. the products are not only addressing health-issues, but also issues of well-being and lifestyle, which are needs of younger adults as well;
b. the company initiating and owning the development process has historically been involved either in the market of younger adults, or in both the markets of younger and older adults;
c. some younger adults also have a need for smart ATs for health issues (like diabetics or sport fanatics);
d. they are an easier market to address, without hampering factors like unwilling caregivers.

The difficulties of defining specific age-limits of older adults, as put forward by Celler, Lovell and Chan (1999) and Fisk et al. (2009), and the considerable differences among individuals as stressed by Cheek, Nikpour and Nowlin (2005) are endorsed by almost every interviewee. To overcome this problem, some developers (mostly in the P&D- and SMD-cases) do not strive to develop individual solutions, but to develop 'container solutions' adaptable to individual needs.

Despite the stressed importance of involving future (potential) users by Noller, Freeney and Peterson (2001), this research has not encountered this phenomenon at all.

However, this research did find evidence of developers considering additional users during a development process, as proposed by Oudshoorn and Pinch (2005). Especially within SMD-cases, additional users are intensively involved because:

a. they (professional and informal caregivers) need to believe (and/or be convinced) that the technology will provide them with accurate and reliable information that enhance their ability to provide care;
b. they (professional and informal caregivers) have to 'use' the SMD-products or derivatives of it, like databases;
c. they (relatives and informal caregivers) must feel that the technology offers them ways to support, and/or care for their loved ones;
d. they (health insurance companies) need to be convinced that the new business models (that are a consequence of the technology) are financially feasible and competitive in the economic climate of healthcare.

Virtually none of the developers of TTA-cases and P&D-cases considers any additional users, either because of irrelevance (TTA-cases) or because of the abundance of additional users (P&D-cases). Consulting this large group of additional users would unnecessary hamper and slow down the development process and is expected to provide conflicting suggestions for improvement of the products.

The discrepancy between defining users in innovation literature and design literature as either end- and additional users or only end-users, is not really clarified by this research. For some technologies, it is important to consider them, while for others (with sound argumentation) this is explicitly not the case. However, many developers struggle with ways to cope with the possible abundance of additional users and their conflicting suggestions for improvement of the products.

6.2 Sources of use information versus design approaches

The second tension found in literature was the difference of the more practical design literature considering user participation to be the only preferred source of use information, against the innovation literature considering also other forms of user involvement valuable and sometimes even preferable.

To start with, interviewees widely endorse the suggestion, put forward by Dosi (1988), and Nelson and Winter (1982), that an innovation process interacts with both demand and supply simultaneously. All cases combined information both from the sides of manufacturers and users.

This research did unexpectedly run into an example of user-innovation, as defined by Von Hippel (1988). One of the TTA-cases started with a relative developing a product that enabled him to monitor his parents, because of their mental decline. Nevertheless, when this developer brought the product to the market, he realized that additional information about use was indispensable, which made this case adjunctive to this research as well. The addition of the differentiation between the applied sources of use information before and after prototyping (which was inspired by Woolgar (1991)), turned out to be useful and in-line with what actually happens in the empirical field. However, it is debatable if for example, ‘user participation after prototyping’ is a less-intense source of use information when compared to ‘direct & indirect representation before prototyping’ (see figure 2 in chapter 2.4).

The results of this research also suggest the sources of use information to be cumulative. When higher intensities of user involvement are applied, usually the lower intensities are also consulted. Further research using this model could try to validate this (or another) continuum and investigate if this cumulative character is meaningful in understanding and describing development processes.

The advocated assumption found in practical design literature that higher intensity levels of user involvement always relate to better design and increased probability of success is doubted by many interviewees. Based on their experience, lower intensity levels of user involvement often result in good design, because it is not important how developers create an ‘image’ about users and use, as long as it leads to technology that is used. Levels of intensity of user involvement are primarily related to the experiences developers already had, before the start of an innovation process; if the developer is inexperienced with the (potential) user group, or when the technology is new for the (potential) user group, he is more likely to apply higher intensity levels of user involvement. The following paragraphs will clarify how the observed consultation of sources of use information during this research relates to the theoretical interpretation of it. Additionally, it will be illustrated (when possible) why developers consider each applied source of use information useful (and sometimes even sufficient) for creating an ‘image’ of their users.

Non- & implicit representation

This type of user representation was described by Peine (2007) as designers/developers who create an ‘image’ of use and users, by referring to (a) their own preferences and skills, (b) stories about use coming from the designers’ professional networks, and (c) insights gained about users or use of previous design processes. The first two sources (originally labeled by Peine (2007) as non-representation) could not be deducted from the data, given the applied method, because they are very implicit types of user involvement which are hard to trace empirically. The third type though was applied quite often. Within TTA-cases it occurred mainly in the form of developers having actually worked with (potential) users in former jobs. During these former jobs, developers not only experienced the problems of (potential) users, but also observed the lack of sufficient solutions and the reasons why existing products did not suit the needs of users. In a sense, this makes the developers also user-experts (i.e. experts with knowledge about use and users). Within TTA-cases this is the only applied source of use information which is additionally explained, because the case-products have a low level of novelty and are essentially not more than a new combination of existing technologies already in use by (potential) users. When the other two case-groups only applied this source of use information, it turned out that the initiating company itself employed user-experts or people who had gained information about users or use during previous design processes. Consulting external sources of use information, like experts or mediators, would in these cases only add to the overall development costs, and not create a 'better image' of use and users.

Representation through ordering customer

This source of use information, which only occurred in P&D-cases, has been added to the original model of Peine (2007), to be able to discriminate representation through ordering customers from the consultation of experts or mediators. This research shows that the influence of an ordering customer is overpowering, while their knowledge is mainly about technical issues, rather than use-issues. On the other hand, they do determine specifications that should be grounded on information about use. This makes it very hard to defend this theoretically as a source of use information, although it is often proponed by developers as their main source of use information.

Direct & indirect representation before & after prototyping

Peine (2007) and Haddon (2002) allocate this source of use information, when users are represented by others than themselves. This representation can be based on general knowledge about users and use (originally by Peine (2007) referred to as indirect representation), or on empirical investigations of (potential) users and use in the specific context of an innovation project (originally by Peine (2007) referred to as direct representation). It was hard to discriminate this latter form of representation from the first one, as expounded in chapter 2.4, and it is therefore combined with the first one. When this source of use information is applied after prototyping, experts or mediators are asked to review a prototype and to comment on it, in terms of usability for potential and additional users. Before prototyping, experts/mediators are consulted to discuss problems of users at stake and concepts that could create a solution to these problems. Direct & indirect representation before and after prototyping are both considered important when either the potential users are new to the company initiating the development process, or when the technology is new for the potential users (i.e. the more radical innovations). Interviewees indicated though, that experts/mediators could be biased when they themselves are additional users as well. This is something that has to be considered preceding the selection and consultation of experts and mediators, because otherwise it could result in an incomplete or incorrect 'image' of potential users. Perhaps it is even advisable to consult the experts/mediators that are also additional users only as source of use information about additional users and not about end-users.

User participation before & after prototyping

This source of use information is defined more or less similarly by both innovation scientists and design professionals, as development processes in which users physically participate, implying that users are actually invited to the site of the manufacturer to discuss the design together with the designers (Fisk et al., 2009; Peine, 2007; Kujala, 2003). Despite the consensus in defining user participation, this is actually the least applied source of use information. Prototypes are sometimes tested, which have characteristics similar to contextual or user-centered design as described by Kujala (2003). However, these similarities only occur when they relate to the consultation of users after prototyping. Before prototyping, users seldom participate in the development process, because:

a. of expected difficulties in the co-development with the potential users of smart ATs in particular (because of both physical and mental limitations);
b. of a belief and/or experience of developers that they are not able to obtain useful information from potential users without the presence of a physical prototype (because potential users have difficulties interpreting and valuing concepts and sketches alone);
c. it puts a large demand on resources (financial and human), which is only feasible for very large companies.

Previous description of sources of use information showed that user participation as advocated by design professionals is only one option to create an ‘image’ of potential users and use and not necessarily the most preferable one. Some other sources of use information could very well be applied or in some instances even replace user participation, without losing quality of the ‘user-image’. Developing useful products in general and smart ATs in particular is not determined by the source of use information applied, but only on the quality of the created ‘image’ of use and user. The degree to which the quality of user-image can be measured or validated is a subject for further research.

7 Conclusions and recommendations

The three sub research questions as well as the main research question are answered in section 7.1, and recommendations are given in section 7.2.

7.1 Conclusions

This research started with the formulation of questions, based on the theoretical differences between the sources of use information as described in innovation literature, and the description of the importance of the role of users in the more practical design literature. Its goal was to relate these two theoretical discussions to empirical evidence gained in the field of the development of smart assistive technologies. This section starts with answering the sub research questions first, which leads to the answering of the main research question.

Sub research question 1: Which potential users of smart ATs are considered during the development process of smart ATs in The Netherlands?

Focusing on actual end-users, none of the studied cases considers younger adults exclusively. They focus either on older adults or on both older and younger adults, although one would expect a focus primarily on older adults, because of the nature of smart assistive technologies. However, some explanations for this counterintuitive broader group of potential users have appeared during the course of this research. Firstly, there appears to be an increased desire of younger adults to enhance their well-being and to control/monitor their own health. Secondly, the occurrence of difficulties in the acceptance of smart ATs in the older adults market, because of obstruction from formal caregivers, forces developers to search for other markets. Finally, many companies that cooperated in this research, historically developed products exclusively for younger adults, and only recently expanded their potential market to include older adults.

Evidence for considering additional users, like formal and informal caregivers, during the development process is minimal, with the exception of cases in which smart assistive technologies with the highest levels of complexity are developed, like SMD-cases. These cases are most closely related to healthcare-issues, and this is given as the main explanation why developers are addressing additional users as well. Additionally, because of the high novelty factor of these case-products, affirmation of the choices made by developers is a more stringent requirement.

Sub research question 2: When is which source of use information consulted in the development process of smart ATs in The Netherlands?

The most frequently consulted source of use information is non- & implicit representation of users, which equals the strategy of developers to create an ‘image’ of potential use and users, mainly based on experiences of former development projects or former jobs. This is not surprising, since it is unlikely that developers/innovators would not apply previous experiences. Additionally, less frequently, developers use direct & indirect representation (such as experts and mediators) as their source of use information, but only after they created a working prototype. Before the creation of a working prototype, experts and mediators are seldom used as source of use information, because most developers do not expect useful input from experts and/or mediators without being able to demonstrate the functionality of a product. The main reason for consulting experts or mediators is not only to obtain knowledge about potential users, but also to convince the experts/mediators of the usefulness of the case-products, so that they will prescribe or recommend them to their patients/clients. User participation after prototyping as a source of use information is also not frequently employed. This is a striking phenomenon, since one could expect that all products have to be tested before being launched onto the market. User participation before prototyping as a source of use information is also uncommon, because of similar reasons as to why experts and/or mediators are not consulted.

Special attention has to be given to the importance of an ordering customer, particularly in the development processes of platforms and domotics. The influence of the ordering customer on the development process is substantial and it (deliberately or unintentionally) puts up barriers for developers to either consult experts/mediators or (potential) users. On the one hand, the importance of the ordering customer is not surprising, because they have 'the money' and thus the 'biggest say'. On the other hand, many ordering customers do not deal with potential users on a daily basis, but are managers or building owners with their own technical ideas and wishes, which are not indisputably based on the potential end-users.

Finally, both the size of the initiating and owning company of a case, and the level of complexity of the case-product, are important characteristics that relate to the use of the different sources of use information. The bigger an initiating and owning company of a case is, the larger is the variety and intensity of sources of use information that are consulted by developers. The relation between complexity of products and intensity of applied sources of use information, are similar. Developers involved in the development of the more complex technologies, are inclined to consult the more intense sources of use information.

Sub research question 3: When would which source of use information ideally be consulted in the development process of smart ATs in The Netherlands?

This question aims at determining whether currently applied sources of use information are the sources ideally applied by the developers, or whether hampering factors are present. The analyses of the results show that, obviously, all cases would prefer to use non- & implicit representation as a source of use information, but that a majority would also prefer to apply direct & indirect representation and user participation after prototyping as a source of use information. Slightly over 50% of the cases studied, would also like to apply direct & indirect representation before prototyping as a source of use information. However, constraints in consulting these sources of use information are a lack of financial resources needed to accommodate such user representation, human resources to organize these types of user representation and an experienced (or expected) lack of interest from professional caregivers. The first two constraints are easier to overcome by larger companies that own and initiate a development process. User participation before prototyping is only considered a valuable source of use information by a minority of the interviewees, because most developers consider a working prototype a necessity for users in order to provide useful feedback.

However, according to the majority of interviewees, one must not focus on the source of applied use information, but on the created 'image' of use and user. If this 'image' is correct and useful for the development of a smart AT, high intensities of user involvement are not considered more valuable than the lower intensities. The results of this research have shown that also the less intense sources of use information are often based on developers' experience with (potential) users or previous research on (potential) users, which makes it easier to understand that applying these sources can also be very fruitful.

Main research question: When and how is information about (potential) users of smart assistive technologies (smart ATs) brought into the design and development processes of smart ATs in The Netherlands?

The main source of use information applied in the development processes of smart assistive technologies in The Netherlands is non- & implicit user representation. Also ordering customers, direct & indirect representation after prototyping, and user participation after prototyping are sources of use information applied by developers of smart ATs, however to a much lesser extent. This is not because most developers consider these sources as unimportant. The majority of developers consider direct & indirect representation and user participation after prototyping very useful, but are hampered in the use of these sources mainly because of a lack of resources (financial and human), and a lack of experience/knowledge of how to apply these sources of use information. However, in the majority of development processes that mainly applied lower intensities of user involvement, developers either had worked with (potential) users in the past, or were involved in previous development processes that gained knowledge about (potential) use and users. When such situation occurs, developers do not generally consider higher intensities of user involvement fruitful for the creation of their 'image' about users and use. Both direct & indirect representation before prototyping and user participation before prototyping are in general not considered useful, because experts, mediators and especially potential end-users are not able to review products and comment on them without a physical product. As long as innovations are based on 'concepts' alone, users are not able to give developers useful information about use.

These conclusions imply that the more practical design literature (which advocates early and intensive user involvement) is relatively far from that what actually happens in the field of the development of smart ATs in The Netherlands, but with legitimate reasons. This research showed that direct user participation is not always preferred, because users are not easy to identify, and users often lack relevant knowledge. Particularly when the size of the potential user group is substantial, it is expected (and in some cases experienced) that the input from users is contradictory, which reduces its value considerably. In addition, developers often hold substantial and sufficient use and user information because of former employment, and initiators (ordering customers) of innovative development processes provide sufficient use and user information. User participation after a prototype has been constructed, is more often considered useful, because developers consider it important to test their products. However, developers conceive user participation as described by the design literature (which most closely resembles 'user participation before prototyping' as named in this research) to have considerable drawbacks. Users (and particularly end-users) of smart assistive products (and probably most other consumer goods as well) participating in a design process, generally lack the ability to provide developers with useful insights about potential use, because they cannot 'understand and interpret' concepts and sketches alone, and because of their (expected and/or experienced) mental and physical limitations. To overcome these drawbacks, developers have to enforce such simplifications to their original idea, that it is highly doubted whether users' feedback is of any use to the development of an original idea. In addition, user participation demands vast financial and human resources, thus making it primarily affordable for larger companies (or innovation processes with substantial budgets).

The innovation literature discussed in this research, provides a much more complete explanation of why specific types of sources of use information are more frequently used when compared to others, and provides an explanation of the successes of certain smart ATs, even when their development process did not consult high intensities of sources of use information. This research cannot rank the types of user involvement for development processes in general, or for smart AT development processes in particular, because the discussed sources of use information as described by innovation literature do not form a normative scale. However, the philosophy on user involvement as advocated and legitimized in the innovation literature is much endorsed by this research.

7.2 Recommendations

If I were to recommend possibilities for further research, it would be to test my elaboration of Peine's model (2007) on types of user involvement in producer-consumer interactions, which discriminates between ordering customers as source of use information and experts. Additionally, research could be carried out to both determine the importance of the different intensity-levels of the various sources of use information, as well as developing methods to measure this. Finally, many interviewees stressed the importance and perceived current lack of sufficient subsidies and up-to-date legislation for a fast and successful introduction of smart assistive products in The Netherlands. I would recommend the Dutch government to make this a priority, before growth of the aged population starts affecting the high standard of health care negatively.

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Appendix A – Interviewees

Cases	Companies	Interviewee	Interview-date
Track, trace & alarm devices			
Casev 1201 & 1202	Casev Optical Services	Casper Evers	August 6, 2009
Homesafety alarmsysteem	Essential Domestiq Services B.V. (Homesafety)	Yossip de Jong	September 30, 2009
My-SOS	My-Bodyguard B.V.	Rob Kuipers	September 18, 2009
Optipager	DAZA Opticare B.V.	Carlo Danen	August 24, 2009
Quogle	Quogle B.V.	Kees Casander	September 24, 2009
Secufone	Secufone B.V.	David ter Ellen	October 5, 2009
TrackJack - Basic Edition	TrackJack B.V.	Remco Sjoerdsma	September 22, 2009
Platforms/domotics			
Amido	Ascom (Nederland) B.V.	Ruud Lohuis	July 8, 2009
	Ascom (Nederland) B.V.	Bart Sonnemans	August 26, 2009
	DAZA Opticare B.V.	Carlo Danen	August 24, 2009
	Alphatronics B.V.	Cojan Prins	October 9, 2009
Home Control Box	Home Automation Europe B.V.	Hanneke van der Horst	August 27, 2009
	Home Automation Europe B.V.	Arnoud Snijder	September 21, 2009
iDAP & VHT	CPS Europe B.V.	Ludo Zwaan	July 1, 2009
IRS 5G	IRS B.V.	Boudewijn Hoekstra	September 28, 2009
	Fifthplay N.V.	Erik van Mossevelde	October 29, 2009
Unicare	CLB Benelux B.V.	Ron Telleman	November 18, 2009
Viedome	Mextal B.V.	Frans Stravers	September 24, 2009
Verkerk Service Systemen	The Verkerk Group B.V. (Service Systemen)	Rik van Dijk	August 31, 2009
	The Verkerk Group B.V. (Service Systemen)	Rob den Engelsen	September 25, 2009
	MVAVD Design	Marcel Vroom	November 9, 2009
Smart medical equipment			
Connected Care	Koninklijke Philips Electronics N.V. (Philips Design)	Mili Docampo-Rama	October 1, 2009
Medido Connected	Innospense B.V.	Bartel Timmermans	August 10, 2009
	Innospense B.V.	Thijs van Nuenen	September 16, 2009
Real Time Medication Monitoring	Evalan B.V.	Henk Schwietert	July 17, 2009
	Evalan B.V.	Thomas Rubbens	August 29, 2009
	Inspiro B.V.	Frank van Eck	August 4, 2009
SmartBlister	The Compliers Group International B.V.	Jos Geboers	June 30, 2009
	The Compliers Group International B.V.	Willem Kort	August 14, 2009

Appendix B - Questionnaire

Company information:

1. Size
2. Main activities
3. Experience in the field of smart ATs
4. Background of interviewee

Product smartness

1. What does the product do in the market?
    a. Is the product able to:
        i. communicate with other products (e.g. a digital camera with personal computers),
        ii. able to process information (e.g. a heat thermostat that takes into account the outside temperature before switching on),
        iii. able to perform tasks autonomous (e.g. a lawnmower that measures the length of the grass and based on that decides to mow the lawn)
2. Which level of complexity does the product have? (Mann et al., 2005)

Product assistiveness

1. What kind of problems does the product solve?
2. Can the assessed product be considered assistive?
    a. Does it enhance a person's well being at home?
    b. Does it enable to live individually,
    c. Does it enable to live integrated in society?

User Involvement – Which

1. Which users are considered in the design and development processes of smart ATs
    a. Which users were initially considered?
    b. Did this change over time? If so, why?
    c. Did you consider involving future potential users with a conceivable need besides current potential users?
    d. How did you deal with the variety in capabilities between 'very' old adults and 'almost' old adults?

2. Is there a particular focus on older users? If so:
    a. How is dealt with reduced auditory and visual capabilities?
    b. How is dealt with cognitive disabilities (Short-term memory, Semantic memory, Event/time-based prospective memory, Procedural memory?
    c. How is dealt with the reduced control over movements of older adults?

User-involvement – How

1. How are users represented in the development process?
    a. Based on what information (or from whom) did the designers created an 'image' of their potential user? (real, or through mediators and/or experts?)
    b. Was it ever considered to involve experts, mediators, or potential users in the design process?

User Involvement – When

1. If user are involved in the design process, when in the process are they considered?
    a. What are the different stages of the design process? (e.g. (1) gearing-up or front-end analysis phase, (2) the initial design or usability testing phase, (3) the iterative design and development phase, and (4) the final test and evaluation phase.))
    b. How long did every stage take?
    c. How many employees were involved in each design stage? (Can I interview them too?)
    d. When in the design process were users considered?

Design consequences of user-involvement

1. What are (or have been) design-consequences of user-involvement?
    a. Could you mention specific changes to the design, based on insights gained from user involvement?
    b. When were these design changes implemented during the design process?
    c. Do you think that involving older users is likely to result in universal design, or only to design for older adults?

Ideal design process with its constraints

1. How would you describe the ideal design process for designing smart ATs? Specify:
    a. if users should be involved
    b. which users should be involved (only older users or also users with a conceivable need, family, care givers)
    c. how should users be involved (participation, through mediator/experts)
    d. when should users be involved (only at the beginning/end during the entire process)

2. What are the major constraints for involving users in the design process?

Appendix C - Case summaries

Out of confidentiality reasons, the case summaries are left out of this public version.

Appendix D - Decoded results

TTA-cases	CSV 1201/02	Homesafety	My-SOS	Optipager	Quogle	Secufone	TrackJack
Size of initiator/owner of the development process	1	2	1	1	1	2	1
Considering only older adults important	1	0	1	1	1	1	0
Considering both younger and older adults important	0	1	0	0	0	0	1
Considering informal caregivers important	0	0	0	0	0	0	0
Considering formal caregivers important	0	0	1	0	0	0	0
What is current practice:							
Non- & implicit representation	1	1	1	1	1	1	1
Involvement of ordering customer	0	0	0	0	0	0	0
Direct & indirect representation after prototyping	0	0	0	0	0	0	0
User participation after prototyping	0	0	0	0	0	0	0
Direct & indirect representation before prototyping	0	0	0	0	0	0	0
User participation before prototyping	0	0	0	0	0	0	0
What is ideal practice:							
Non- & implicit representation	1	1	1	1	1	1	1
Involvement of ordering customer	0	0	0	0	0	0	0
Direct & indirect representation after prototyping	0	1	1	1	1	1	0
User participation after prototyping	0	1	1	1	1	1	0
Direct & indirect representation before prototyping	0	0	1	1	1	0	0
User participation before prototyping	0	0	1	1	1	0	0

P&D-cases	**Amido**	**HCB**	**iDAP & VHT**	**IRS 5G**	**Unicare**	**Viedome**	**VSS**
Size of initiator/owner of the development process	3	2	2	3	3	3	3
Considering only older adults important	1	0	0	0	0	1	1
Considering both younger and older adults important	0	1	1	1	1	0	0
Considering informal caregivers important	0	0	0	0	0	0	0
Considering formal caregivers important	0	0	0	0	1	1	1
What is current practice:							
Non- & implicit representation	1	0	0	1	1	1	1
Involvement of ordering customer	1	1	1	1	1	1	1
Direct & indirect representation after prototyping	0	0	0	0	1	1	0
User participation after prototyping	1	0	0	1	1	1	0
Direct & indirect representation before prototyping	0	0	0	0	1	1	0
User participation before prototyping	0	0	0	0	0	0	0
What is ideal practice:							
Non- & implicit representation	1	1	1	1	1	1	1
Involvement of ordering customer	1	1	1	1	1	1	1
Direct & indirect representation after prototyping	1	0	0	1	1	1	1
User participation after prototyping	1	0	0	1	1	1	1
Direct & indirect representation before prototyping	1	0	0	0	1	1	0
User participation before prototyping	1	0	0	0	0	0	0

SMD-cases	CC	Medido	RTMM	SmartBlister
Size of initiator/owner of the development process	3	1	1	3
Considering only older adults important	0	1	0	0
Considering both younger and older adults important	1	0	1	1
Considering informal caregivers important	1	0	0	0
Considering formal caregivers important	1	1	1	1
What is current practice:				
Non- & implicit representation	1	1	0	1
Involvement of ordering customer	0	0	0	0
Direct & indirect representation after prototyping	1	1	1	1
User participation after prototyping	1	1	1	0
Direct & indirect representation before prototyping	1	1	0	0
User participation before prototyping	1	0	0	0
What is ideal practice:				
Non- & implicit representation	1	1	1	1
Involvement of ordering customer	0	0	0	0
Direct & indirect representation after prototyping	1	1	1	1
User participation after prototyping	1	1	1	1
Direct & indirect representation before prototyping	1	1	1	1
User participation before prototyping	1	0	0	0