User-Centered Design of Intelligent Environments: Requirements for Designing Successful Ambient Assisted Living Systems

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Abstract. *This paper illustrates the importance of involving end users into the design process of Ambient Assisted Living applications. It especially focuses on two crucial aspects, the involvement of senior users and the home as the primary application domain. Based on this theoretical foundation, requirements for successful system design are elaborated.*

Keywords. User-Centered Design, Ambient Assisted Living, Intelligent Environments, Design Requirements.

1 Introduction

Today, the design of new homecare solutions is mainly driven by technical considerations of medical professionals and system providers [4]. Developments in this field are often demonstrations of technological possibilities [22] rather than responses to the actual needs of potential users [45][64], which is often cited as one of the main reasons for poor adoption (see, e.g., [23], [27], [33] or [65]). One reason for this problem is a lack of knowledge on the developer's side. System designers and engineers usually have very profound expertise about technical possibilities, but only very limited insight into the social context in which their products will be used [33][43][51][71] [72]. Quigley and Tweed [53] even argue that "visions of what technology can do for the elderly are rarely based on any comprehensive understanding of needs and in some cases are blatant technology push".

Despite these obvious shortcomings in the development of new technical products, user integration still does not take place in many companies [6][11][54]. Financial constraints and time pressure are the most often cited reasons for not integrating users in the design process of new technologies [30]. With respect to medical technologies this means that "many products are not accessible to large sections of the population [as] designers instinctively design for able-bodied users and are either unaware of the needs of users with different capabilities, or do not know how to accommodate their needs into the design cycle" [10].

The importance of user-centered design approaches was demonstrated in numerous studies. For example, Ziefle and Bay [78][79] showed that age-sensitive design concepts could significantly reduce age-related handicaps and thereby enable older adults to efficiently operate new technologies. However, user-centered design does not only bring benefits to end users due to better usability of medical products, but is also likely to lead to substantial financial advantages for manufacturers and service providers as the costs of adapting technical concepts and service functionalities are considerably lower in early design stages [70]. Therefore, it is important to involve future users in explorative studies as early as possible in the design process of new products [28].

When doing this, it is vital to focus in particular on two aspect, which are often neglected in existing work: the involvement of senior users and the home as the main application domain. Both aspects will be outlined in the following sections.

2 Integration of Older Users

The vast majority of technology acceptance studies conducted in the past explored the diffusion of information and communication technologies in work environments and regarded young and middle-aged workers as their target user groups [58][61][62][59][57][60]. In contrast, Ambient Assisted Living (AAL) environments will be mainly inhabited by older users and people with mental or physical handicaps, who have different requirements than standard computer users typically investigated in technology acceptance studies [22][31][77]. Therefore, it is important to integrate elderly users in the design process and empower them to influence ongoing developments according to their personal

needs [36][56][80][81][82][83][84]. This is especially critical as older users will inevitably be lead adopters for electronically-enhanced healthcare solutions [13].

In order to define who is considered old, researchers in the field of gerontology are often using chronological thresholds [43]. However, the chronological age of an individual is often not a reliable predictor for the person's mental and physical abilities as health states of elderly people vary dramatically [75]. This is validated in several studies that found that people in average felt 10 to 15 years younger than they actually are [76]. As a result, elderly people are often clustered into groups depending on their health state instead of their age. Usually, elderly people are divided into three groups: active seniors, elderly people with declining abilities, and old people with severe disabilities (see [9] or [49] for more details).

While this might be a useful classification for general usage, such a generic classification scheme is not sufficient for the development of future homecare applications. Instead of designing for generic groups of older people, it necessary to address age-related shortcomings on an individual level. This is of particular importance as the effects of old-age illnesses and disabilities are highly individual, which results in a much higher heterogeneity of elderly people compared to younger ones [26][46][73][77]. Hence, many authors including Bierhoff et al. [7] argue that there is not such a thing as a typical older user. Instead it is necessary to design for a broad diversity of users, who are highly variable with respect to their individual physical and mental capabilities [49].

As mentioned above, the majority of existing research has focused on work and especially office environments as the main application area. While the nature of the implemented systems might be similar from a technical point of view, the social context in which they are used is completely different. Social interactions in work environments are characterized by being mostly formal, structured and goal-oriented, compared to activities in home environments, which are not only more informal and less structured, but also targeting at a more enjoying and entertaining usage experience [45].

Current design approaches are based on empirical knowledge gained in work settings and are often ”grounded in the core rationalities of production, efficiency, [and] the organization of labour” [15]. When developing home technologies it is often neglected that such design rationales cannot be transferred from a work to a domestic setting as “motivations, concerns, resources and decisions [of home users] can be very different from those found within workplaces” [34]. This conceptual mismatch is especially reflected in a poor acceptance of new assistive technologies. While AAL systems can provide personalized medical assistance and thereby enable an independent lifestyle for older people, many existing products are not fully accepted by potential users [30]. Fichten et al. [25] even estimate that nearly half of all people who need assistive technologies actually use them.

Poor or unexpected usage [1] shows that the actual needs and desires of end users are not yet met by developers. When addressing this problem it is important to be aware that technology acceptance is a highly situational phenomenon. The acceptance of new technical devices “depends on the subject of acceptance, the object of acceptance and the context of acceptance” [65]. So far, there is an extensive body of literature about the usage of information and communications technologies in work settings, but very little knowledge about the social context of technology usage in the home [33]. Hence, it is crucial to specifically study the usage of future healthcare technologies in home situations, instead of trying to transfer existing knowledge from other application domains. The design of successful medical technologies for home usage requires therefore a close collaboration with potential end users in order to fully understand the context of later usage [4].

4 Design Requirements

4.1 Medical Usefulness

Perceived medical usefulness is undoubtedly one of the most important factors for the acceptance of AAL applications (see, e.g., [29], [65] or [66]). Consequently, the medical advantages of technology-supported medical services have been proven in numerous studies. For example, Dansky et al. [16] studied the effects of tele-medical homecare on the clinical outcomes and the associated financial costs and found positive effects with respect to both factors. Hui et al. [38] studied the feasibility of using tele-medical services in a nursing home and found significant advantages of remote care provision with respect to medical and financial aspects. Comparably positive results were also found in studies exploring the efficacy of a remote blood pressure monitoring application [63] as well as the effectiveness and medical costs of a tele-care application for patients with congestive heart failure [39].

These individual results are underpinned by Hailey et al. [32], who conducted a meta-analysis of 46 existing tele-medical studies and found that over 2/3 of the studies identified benefits of tele-medical applications over classical approaches. Studies by Riegel et al. [55], Kobza and Scheurich [42], Tsang et al. [69], Whitlock et al. [74] and di Biase et al. [24] came to similar results.

So far, the majority of studies evaluated the medical and financial effectiveness of tele-medical applications. Even if some of the results might be transferable to Ambient Assisted Living systems, technical feasibility alone won't be sufficient for the large-scale diffusion of future systems (see, e.g, [65]).

Based on their ongoing research, Hirsch et al. [35] even argue that the assumption older or handicapped people "will use an assistive technology simply because they need it is misguided". Especially in home settings, it is crucial that users accept such applications in order to voluntarily use them.

4.2 Accessible Design and Usability

Today, it gets more and more accepted that the usage of smart home care technologies depends on a variety of different and interrelated factors [7][41]. Accessible design and usability are probably the two most cited criteria in this context (see, e.g., [5], [8], [20], [21] or [30]). While these are undeniable crucial system requirements, there is a considerable number of additional design aspects, which are far less discussed in literature, but equally important for good system design. The following sections take a closer look at these aspects.

4.3 Feedback and Control

Compared to traditional desktop-based computer systems, which rely nearly completely on explicit user input, Ambient Assisted Living systems are often envisioned as autonomous helpers. Hence, it is not surprising that most early context-aware system did not address user control as a design factor. Over the last couple of years this general attitude slowly started to change. Today, many authors including Davidoff et al. [17], Poulson et al. [52] and Bierhoff et al. [7] regard user control as a key requirement for the successful design of any Ambient Assisted Living application. Contrary to a common belief of many system designers, most elderly people want to be actively involved in the usage of home technologies [12].

Providing adequate feedback and control mechanisms is vital for the acceptance of smart home applications in general [37][47][50]. When designing AAL systems, special attention should be paid to intuitive control and feedback mechanisms for enabling user-centered patient monitoring. This does not only include understandable feedback about the areas, parameters and persons being monitored, but also transparent information about the people who are able to access these data as well as easy ways to completely deactivate the monitoring process [45][47].

4.4 Integration into Daily Life

According to Alexander [3] everyday life is structured through "patterns of events" that repeat themselves over and over again. More precisely, we can say that "our lives are organized through reoccurring patterns of work, leisure, travel, relaxation, and the rest" [15]. Consequently, it is the designer's task to develop home care technologies that adapt to the user's daily routines, instead of the other way round. In this context, it is of particular importance that new homecare services "consider 'old' habits of the users" [7] and by doing this minimize "the disruptive nature of new technology" [4]. Studies show that potential users of smart home technologies want future homes to be similar to their existing homes [19]. Hence, de Ruyter et al. [18] argue that the main challenge of smart homecare technology is not the physical integration of medical devices into the domestic space, but "to socially integrate the system behavior into the fabric of everyday life".

4.5 Personalization and Natural Interaction

Results from a focus group study conducted by Lull et al. [44] show that AAL systems have to be designed such that they are flexible enough to be individually adapted to personal user needs. This is a particularly important requirement with respect to the design of user interfaces [52]. Many authors including Abowd and Mynatt [2] stress the fact that this includes a paradigm shit away from traditional desktop interfaces towards intelligent user interfaces that support implicit interactions [67].

4.6 Aesthetic Design

For a long time, aspects of aesthetics played a minor role in the field of human-computer interaction [68] and it took considerable time until the perception of aesthetic design slowly started to change. Today, an aesthetically pleasing design is widely accepted as a crucial factor determining the success of new technological products (see, e.g., [4], [40], [45] or [76]). In this context, Hirsch et al. [35] even argue that while "traditional usability factors determine whether a device can be used, aesthetic factors determine whether a device will be used".

4.7 Avoidance of Stigmatization

However, good design does not only refer to the aesthetic qualities of a system, but also includes a visual appearance, which does not contribute to the stigmatization of its user. Authors, like e.g., Hirsch et al. [35] or Ballegaard et al. [4] argue that many existing medical support systems are stigmatizing and continuously remind users of their illness or disability, if they are not completely rejected right from the beginning. Wide-spread user adoption will only take place if future home care systems are designed such that they do not highlight the users' disabilities [7][35][76], but "support a positive self-image for the elderly persons" [12]. Consequently, Cowan and Turner-Smith [14] argue that the goal should be to develop home care systems, which are not only "attractive to own", but provide "ability without removing status".

5 Conclusion

Involving potential users in the design process of new applications is essential for the long-success of Ambient Assisted Living applications. When doing this, it is of particular importance to especially focus on senior users as the main target group of Ambient Assisted Living applications and the home as the primary application domain. Both aspects have been addressed in the detail in this paper.

Following a user-centered design approach also involves to take a more holistic look at relevant design criteria. Medical usefulness and technical feasibility are undoubtedly key requirements for successful system design, however, these factors alone won't guarantee that new systems are accepted by potential users. This paper discussed a number of important design requirements and illustrated how these aspects could be integrated in the design process.

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