Understanding Requirements for Textile Input Devices Individually Tailored Interfaces within Home Environments

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Abstract. In the last few years, many countries showed an increased public awareness regarding the consequences of the demographic change, which presents considerable challenges on future health care systems in the next decades. As a framework of the research presented here, we introduce a currently running interdisciplinary research project in which novel textile input devices are to be developed, iteratively designed, and evaluated. In order to learn about the individual requirements for using smart textiles in a home context, we carried out a exploratory questionnaire study in which 72 participants (aged 20-76) evaluated perceived benefits and barriers of smart textiles in the home context. Results show a first insight into user experience and the general willingness to adopt smart textile input devices. Also, the perceived suitability of functions to be controlled by those novel input devices as well as the reported appropriateness of different rooms and general device styles into which smart input devices could be integrated were collected. Results show, overall, a high willingness of participants to use smart textiles as input devices.

Keywords: Smart textiles, technology acceptance, user diversity.

1 Motivation and Related Work

Drastical demographic changes and aspects such as increased life expectancy, improved medical healthcare, or reduced fertility rates, will lead to a growing number of frail older people who will need medical treatments and long-term care provided by public health care systems [1] [2]. In order to master the exigent requirements of an aging society, developments in medical engineering in combination with information and communication technologies are indispensable to offer novel or improved possibilities for older patients to keep mobile and maintain their independence in old age

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[3] [4] [5]. The spectrum of emerging technical applications covers a broad variety of developments, reaching from internal medical technologies (e.g. implants for monitoring physiological signals) over devices integrated into clothes (e.g. smart textiles, wearable technologies) to healthcare robots or smart home technologies that support older people in keeping up their independent life at home [2] [6] [7]. So far, research on medical technology is mostly dominated by technical, medical, and economic disciplines. The same holds true for the development of new medical products, which are in most cases guided by medical necessity, technical feasibility, and economic interest [8]. This exclusively technical and economic focus on technological advancement disregards the actual end-users' motives and possible barriers to the technology from all aspects of the design and development process. However, medical technology – especially in the home-care and rehabilitation sector – can only tap its full potential and benefit graying societies if the people who will need to use the devices help develop them to fit their specific requirements. This includes clearing acceptance barriers of electronic applications [9] [10].

Supporting seniors in maintaining independent lifestyles at home will only be achievable by systems able to monitor and control health-related information. The devices should also be portable and communicable, and fit into the ecology of existing mobile devices as well as into the individual home context of older adults. This is referred to as Ambient Assistant Living [11] [12]. Though the development in mobile technology is impressive, practical experience shows that technical solutions – novel and timely as they may be – do not necessarily guarantee the successful distribution of these innovations. In order to reach a high degree of user acceptance, taking into account only the technical and engineering aspects is not sufficient. The human aspects of these technologies have to be carefully considered as meeting users' wants and needs regarding privacy, dignity, and individual requirements is pivotal for the users' approval of these medical technologies [13] [14]. Thus, the success of (future) technologies at home largely depends on the extent to which technical developments meet the specific needs and demands of users, and on their willingness to use and integrate devices into their personal spaces [15] [16].

As a framework, we introduce a currently running interdisciplinary research project in which novel textile input devices are to be developed, iteratively designed, and evaluated. We report on a first empirical study in which users' attitudes and perceived requirements regarding textile input devices were explored.

2 Smart Textiles

Smart textiles and clothing represent a promising approach within pervasive healthcare systems. Instead of additional mobile devices, which have to be deliberately picked up and packed, the concept of 'wearable computing' envisions computers as integral parts of our everyday clothing [17]. The goal is to have an always-on and networked computational artifact that assists mobile users in a wide range of everyday situations. Smart textiles can collect different vital parameters, which can be delivered by WLAN to patients' smart phone or computer, the doctor, or even central

emergency stations that call an ambulance if necessary [18]. In the last years, a considerable number of approaches integrated communication and sensor technologies into clothing such as shirts and belts or jewelry and wristwatches [19] [20]. In the context of smart shirts, the most popular approach is the Vivo Metrics Life Shirt [21], on the market since 1999, which is equipped with sensors that measure heart and pulmonary as well as other vital values. Other approaches focus on user experience and are based on fun and hedonic aspects [22], communication aspects [23], or sports [24].

Beyond the high potential of smart textiles in terms of functionality, ubiquity, and effectiveness [17] [19], the approach to integrate technical devices or technology into materials familiar to all persons opens up a huge field of applications scenarios. Textiles are usually perceived positively, based on inherent characteristics of the tissue – soft, warm, chic, pleasurable, smooth, velvety, colorful – which makes this technology highly plausible and usable for different usage contexts [4] [18]. Many users wish for more than the pure technical functionality and prefer devices with a high social and hedonic value [26] [27] [28]. As smart technical devices will be increasingly used within home environments, these aspects are likely to gain additional importance in the future [29] [30] [31] [32].

This is of special relevance against the background of user diversity and the challenge to meet age-related changes (psychomotor, cognitive), as well as the sensitive tradeoff between assistance and the wish to live independently from technology, which is often found in older users [33] [34] [35]. In this context, it is crucial to understand the users' needs, the perceived benefits and barriers a technical device may bring for them, potential design requirements that must be individually tailored to the users' abilities, but also the interrelation of functional and aesthetic factors and their consequences for the design, use, and acceptance of smart environments.

3 Intuitex – An Interdisciplinary Project

"Intuitex" is a recent project, funded by the German Ministry of Education. It specifically targets the development of a novel technology which adapts to the users' needs (instead of the other way around) and which seamlessly fits into the natural living space of users. This claim includes not only a true understanding of users' acceptance and their wishes for usable designs but also an understanding of the interrelation of the use of such technical devices in context. The overall goal is to develop an individually tailored textile interface that can be used in the home environment. In Figure 1 shows schematic drawings of potential application scenarios.

A specific focus of the project is directed at the diversity of users, that is the older and frail users and their requirements for usable and well-accepted technical products. Specifically, the project directs to the holistic and human-centered design of textile input devices that are (1) intuitively usable and easy to learn, (2) respect requirements and lifestyles at home, (3) fit to age-related difficulties in the manual control of input devices, (4) have an attractive design and rely on familiar soft and warm fabrics, and (5) may be suitable for different usage contexts.

In the course of the project, we will implement users' requirements into the technological cycle and develop prototypes in iterative cycles with users evaluating the usability, the design, the aesthetics, and the functionality in each of these cycles.

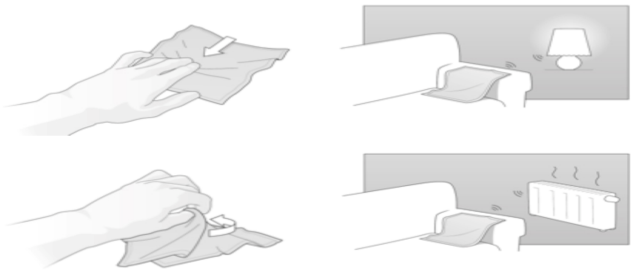

Fig. 1. Schematic drawings of potential applications of smart textiles within the home environment ® Intuitex, RWTH Aachen University

4 Method

Variables and Procedure. Independent variables were the participants' age and gender. In terms of user diversity, both factors might have a distinct effect on the acceptance of smart textiles and the perceived benefits and barriers [4] [8]. In order to collect comprehensive opinions of a broader sample of different ages, we chose the questionnaire-method. The questionnaire was delivered online (completing it took about 20 minutes).

Participants. A total of 72 people participated in the survey (57% female). Their age ranged from 20-76 years (M=29.6, SD=9.8). Participants were reached through the social networks of younger and older adults. They were not remunerated for their efforts, but were keen to learn about innovations in home automation and smart textiles. Only a small fraction (1%) had previous experience with smart textiles, yet about 30% had already heard about the possibility of using smart textiles (mainly from the area of sports).

Structure of the Questionnaire. The questionnaire was arranged into five sections.

1. *Demographic data.* The first part included demographic data regarding participants' age, gender, educational level, and (previous) profession.
2. *Benefits and barriers of smart textiles*. Users were asked to evaluate benefits and barriers of smart fabrics in clothing and furniture (items were the same for both types of textiles to allow a comparison, answered on a 6-point Likert scale.
3. *Requested functions to be controlled by textile input devices.* In a third part, participants were asked to evaluate functions to be controlled by a textile input device. Again, evaluations had to be done on a 6-point Likert scale.

4. *Devices desired as textile input devices.* Participants had to evaluate which possible object or device should be used for the integration of textile input devices.
5. *Home locations in which textile input devices should be integrated.* Participants indicated which rooms at home might be appropriate for the integration of textile input devices.

Questions. The items and answering options were based on previous empirical work in our workgroup in which we collected argumentation patterns as well as user experience of users of a wide age range [36] [37] [38]. In Table 1, items are given.

Table 1. Items and answering options in the relevant sections

Benefits and barriers	Material quality is very important to me • My key criterion is functionality • It is very important that textiles are easy to clean • Material quality is very important to me • I would pay more for a good quality • Durability is important to me • A lower quality is ok if the price is low • Low prize is most important to me • The design is most important to me • High quality is not that important to me • My key criterion is a fashionable look
Requested functions	• un/look front door • open/close front door • turn on washing machine • set alarm clock • control radiator temperature • draw a bath • water plants • control room temperature • switch TV channel • adjust/change music • set outside lighting • open/close shutters • control interior lighting
Requested devices	• curtains • carpets • trousers • blankets • table clothes • pillow • plush toy • kerchief • chair/easy chair
Requested locations	• children's room • bathroom • dinging room • kitchen • table clothes • office at work • office at home • living room

5 Results

5.1 Evaluation of Smart Textiles (Contrasting Furniture vs. Clothing)

We report on descriptive outcomes, followed by the effects of age and gender on acceptance (M)ANOVA). The level of significance was set at 5%. First, the evaluation of smart textiles in furniture (Figure 2) in contrast to clothing (Figure 3) is described.

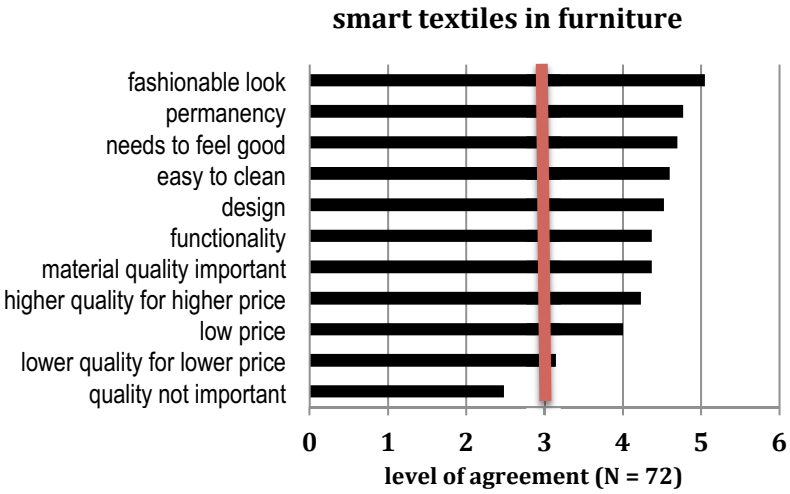

Fig. 2. Level of agreement (means) for the total group regarding requirements of smart textiles implemented in furniture (1 = I do not agree at all, 6 = I completely agree)

When focusing on furniture, we see that the most important dimensions are the "look and feel" and the durability of the material, but also the ease of cleaning and the functionality. Age did not impact the evaluations of smart textiles in furniture. However, there was a significant overall effect of gender ($F(1,42)=2.4$; $p=0.02$), showing that men and women evaluate the use of smart textiles in furniture differently.

A closer look into the single items show that men report to accept more frequently a lower quality to the advantage of a lower price than women do ($F(1,42)=3.8$; $p=0.05$). Furthermore, women report to attach a higher importance to the design of furniture equipped with smart textiles than men ($F(1,42)=3.8$; $p=0.05$). Also, women report to focus much more on the look and feel of smart furniture than men report to do ($F(1,42)=6.4$; $p=0.001$). Interacting effects of age x gender were not observed.

Regarding the evaluations of smart textiles in clothing (Fig. 3), the most important characteristics were the "need to feel good," fashionable looks," "importance of material quality," but also the "durability" of the clothes as well as the "design."

Age did significantly impact the evaluations. The older focused significantly more on the functionality of smart clothing ($F(1,42)=4.9$; $p=0.03$) and attached a higher importance to the "feel good" compared to young adults ($F(1,42)=3.6$; $p=0.05$). Also, gender effects appeared: Durability of smart clothing was more important to men than for women ($F(1,42)=3.7$; $p=0.05$).

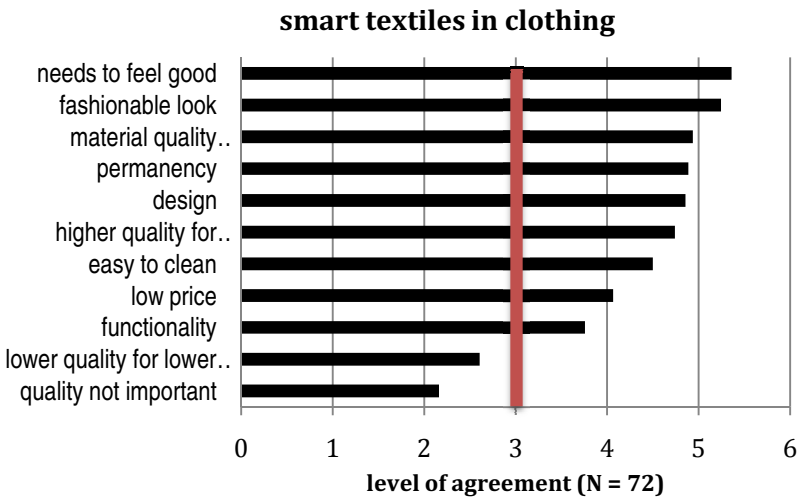

Fig. 3. Requirements of smart clothes (1 = do not agree at all, 6 = completely agree)

5.2 Evaluation of Smart Textiles for Device Types, Functions, and Locations

In addition, it may be important which specific device will be equipped with smart textiles and serve as an input device (Figure 4).

As can be seen, there are clear smart textile "favorites": table clothes, easy chair, outerwear, and kerchiefs were the preferred device types (M = 4.3/6 points). Regarding user diversity, significant age effects for the evaluation of smart textiles in blankets ($F(1,42)=3.4$; $p=0.05$), trousers ($F(1,42)=6.3$; $p=0.02$), and outerwear ($F(1,42)=3.6$; $p=0.05$) were found. Older users evaluated smart blankets (old: M = 3.6; young: M = 2.5), trousers (old: M = 3.5; young: M = 2.2), and outerwear (old: M = 4.3; young: M = 3.3) as more suitable than the younger group did.

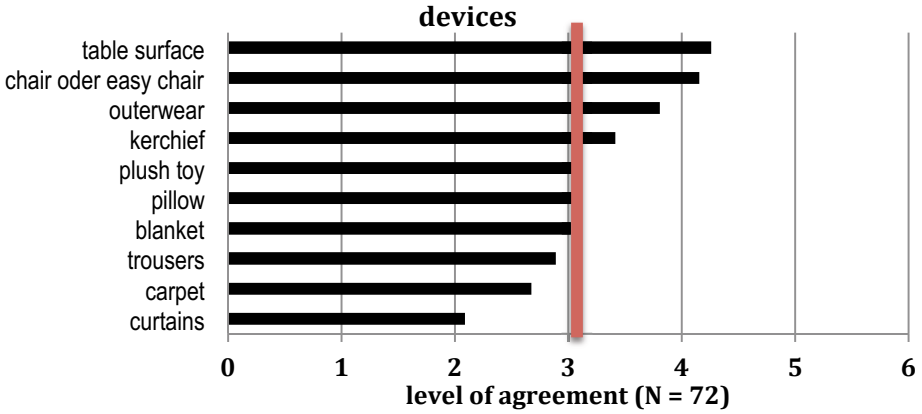

Fig. 4. Perceived usefulness of **device types** (1 = do not agree at all, 6 = completely agree)

The next analysis explored for which functionalities participants perceived smart textile input devices as useful (Figure 5).

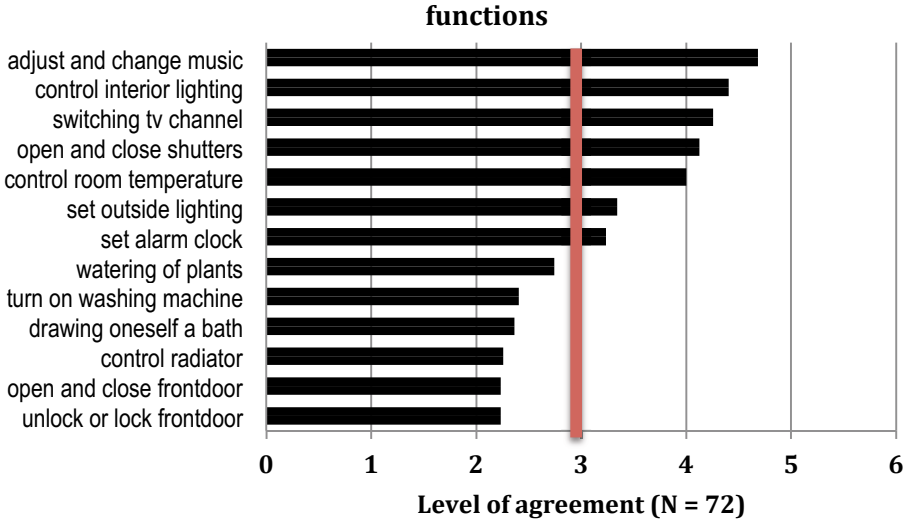

Fig. 5. Perceived usefulness of smart **functions** (1 = do not agree at all, 6 = completely agree)

A final question regarded the evaluation of a suitable location within home and working environments (Figure 6). As can be seen, there are clear preferences. The living room and offices are perceived as most suitable. In contrast, bathroom and children's room are not regarded as appropriate for textile input devices. While both main effects (gender as well as age) did not affect the evaluations differentially, there was a significant interaction effect between gender and age ($F(1,42)=2.9$; $p=0.01$).

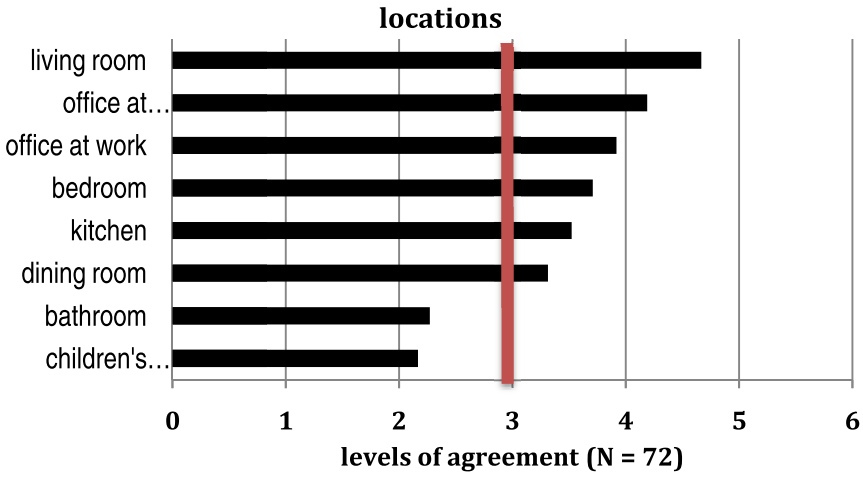

Fig. 6. Suitable **locations** for smart textiles (1 = do not agree at all, 6 = completely agree)

The interaction of age x gender is due to the fact that older men are more positive to use smart textiles in the respective locations than younger men and older women more reluctant than younger women (Figure 7).

Fig. 7. Interaction of age x gender of smart textile input devices in the kitchen (1 = I do not agree at all, 6 = I completely agree)

6 Discussion and Future Work

In this exploratory paper, we report on the perceived suitability of smart textile input devices integrated into home environments. Overall, there was a high openness to use novel devices in all participants, independent of user diversity. The acceptance of users seems to be higher in familiar objects and not sensitive to usage context. As such, smart textiles integrated in clothes are rated as more suitable than smart furniture, presumably because smart shirts are fairly well known from the sports context and already available on the market [21] [22][23]. Regarding possible functionalities and locations at home, users prefer those settings in which the usage of smart textile input devices is not too intimate (living room and office) and only used for fairly neutral and public functions (e.g., switching TV or music channels). The more sensitive the location and the more security-relevant the function (e.g., bathroom, closing the front door), the lower was the perceived suitability of smart textile input devices.

Even though the reported findings about the acceptance of smart textiles were quite insightful, we should be aware that the questionnaire method applied here allows only a first glimpse into users' attitudes and "what users really feel." As most of the users do not have any experience with the handling of smart textiles, the outcomes presented here lack mostly practical knowledge and factual validity. In the course of the project, therefore, the creation of an experimental space in which potential users can experience and "feel" the technology in order to fairly evaluate it is of pivotal importance [39]. Persons might overemphasize their sensitiveness towards privacy and security violations and their dismissal of novel technology if their judgment only relies on the imagination of using it [40]. This is of particular importance, as potential usage barriers can only be fully understood if users can have a hands-on interaction with the environment and "feel" the impact of natural technology at home.

As a general direction of future technology development, it should be considered that the quality of "good interfaces" relies on more than the exclusive focus on performance aspects (as done in traditional studies dealing with the usability of input

devices [33] [34]). Rather, usability should equally focus on traditional pragmatic aspects – attributes emphasizing the fulfillment of individuals' productivity- as well as affective and hedonic aspects – attributes emphasizing individuals' well-being, pleasure, and fun [41] [42]. Especially against the background of an aging society, it is crucial that interfaces are designed in accordance with older users' specificity and diversity [43]. Technical developments should systematically integrate user diversity – age, gender, social and cultural factors – into usability approaches.

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