Intentions to Use Smart Textiles in AAL Home Environments: Comparing Younger and Older Adults

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Abstract. The vision of ubiquitous computing is increasingly picking up pace. An increasing number of everyday objects are equipped with smart technology and start to form the Internet of Things. Yet, interacting with these devices is based on conventional surfaces made of glass, metal, or plastic. We believe that textile interaction surfaces will be the next frontier of ubiquitous computing and identified many blank spots in the research landscape. Peoples' perception and acceptance of smooth and soft interaction surfaces is insufficiently understood. In this paper we present a study in which 90 people of a wide age range evaluated the suitability of smart textiles in different usage scenarios in the home environment. Overall, a solid willingness to use smart textiles as input devices was found, even though there were conditional acceptance criteria which should be given before participants would be willing to buy them. In contrast to many other technology contexts, however, age is not decisive in the evaluation of the usefulness of smart textiles. Younger and older adults seem to have a quite similar evaluation, hinting at a quite generic acceptance pattern.

Keywords: Smart textiles · Age · AAL · Technology acceptance · User diversity

1 Motivation

In 1991 Marc Weiser's and his team at Xerox Parc envisioned the tremendous shift caused by computers shrinking in size and growing in number and capacity [1]. The once bold vision of Ubiquitous Computing is increasingly becoming reality, as more and more everyday objects and devices are equipped with sensors, actuators, computing, and communication technology. The growing number of increasingly intermeshed set of smart objects is slowly but surely forming the Internet of Things [2]. While the increasing penetration of everyday objects with smart information and communication is a relatively new development, one should also consider mankind's past. Humanity uses textiles for at least 30.000 years [3, 4] and they still accompany us every day. Textiles are usually positively connoted and rely on inherent characteristics of the tissue - soft, flexible, elastic, warm, chic, pleasurable, smooth, velvety, multicolored – what makes this technology quite ubiquitous for many different usage contexts [5–7]. As smart technical devices will be increasingly used within home environments [8–10], these

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aspects are likely to gain additional importance in the future [11, 12]. This is of special importance against the background of the demographic change [13, 14]. The challenges raised by the demographic change have been broadly recognized and well formulated in the last decade. In the near future, an increasingly number of older persons need extended long-term care in many societies, and traditional health care systems are not prepared to meet the increased demands, neither with regard to financial necessities, nor with regard to the medical care situation and the care supply chain [11, 15]. The enormous progress in information and communication technology as well as developments in medical engineering open up novel chances for supporting older patients in keeping mobility and maintaining independency at old age [8].

Studies show that older adults wish to maintain their independence as long as possible [16, 17] and to stay longer at home (rather than to move in a senior home), reaching a perceived gain in the quality of life in a familiar environment. In the last few years, the concept of Ambient Assisted Living formed a new understanding of technologically supported living at home [18, 19]. The integration of different kinds of smart sensors in the home environment is able to support seniors in maintaining independent life styles at home, e.g. by monitoring and control health-related information [20]. From a technical point of view, the integration of information and communication technology is basically feasible [21, 22]. From a social point of view, the integration of technology into the sanctuary of the own four walls is fragile [23, 24].

Recent research revealed that "home" is a synonym for retreat and protection in which technology is difficult to become an integral part. Also, rooms are quite differently seen regarding privacy and intimacy and the openness to integrate technology [25].

In order to reach a high degree of user acceptance, the users' perspectives should be considered as well as their requirements towards an accepted technology and their needs with respect to social values (e.g., privacy, dignity, connectedness, communication styles). In short: The success of Ambient Assisted Living necessitates an understanding of people and their willingness to use and integrate technical devices in their personal spaces [26].

2 The Research Context: Textiles in the Home Context

"Intuitex" is the framework of the research presented here, an interdisciplinary project at RWTH Aachen University, funded by the German Ministry of Education (http://www.comm.rwth-aachen.de/index.php?article_id=923&clang=0).

The project aims at the development of user-centered textiles as input devices to be integrated in ambient assisted living environments that adapts to the residents' requirements and which is a seamless and natural part of the daily living space of people. A specific focus is directed to the older and frail people and their requirements for usable and well-accepted technical products that can be used in the home environment. This claim includes an understanding of users' acceptance and the natural and intuitive use of textiles in context. In Fig. 1, schematic drawings of a potential application scenario are pictured, in which textiles are used as input devices to control light or room temperature.

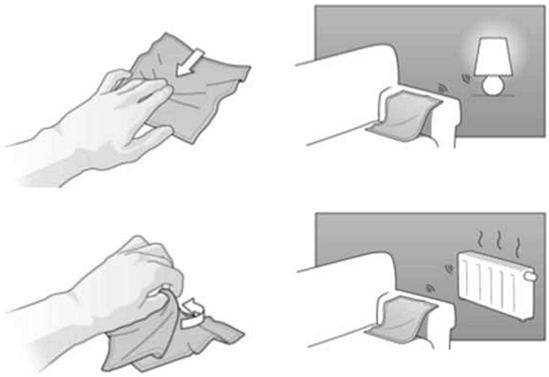

Fig. 1. Schematic drawings of potential applications of smart textiles within the home environment ® Intuitex, RWTH Aachen University.

The input devices need to be easy to use (in order to reach a high user acceptance), and should adapt to age-related difficulties in the manual control of input devices. Also the textiles should have attractive designs with suitable fabrics that fit seamlessly into the living spaces at home. Iteratively, users' requirements are empirically assessed and integrated into the technological development in order to produce prototypes in iterative cycles, with users evaluating the usability, the design, the aesthetics and the functionality in each of the iterative cycles.

In order to understand the perceived utility of smart textiles within the home context, we conducted a questionnaire study, in which users' attitudes towards the use of smart textiles are collected.

3 Method

The questionnaire study was directed to users' attitudes with respect to the perceived or envisioned use of smart textiles in different rooms and contexts at home. The study was assumed to catch a broad view on the topic, quantifying the benefits and barriers. Items used 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 [5–7]. The questionnaire was delivered online and completing it took about 20 min.

3.1 Participants

A total of 90 persons volunteered to take part in the study (58.9 % female). Participants were reached through the social networks of younger and older adults. In order to analyze age effects, the whole sample was split in three age groups. Age group 1 - "the younger ($\leq$30 years)" – consisted of 53 persons, with a mean age of 24.1 years (SD = 3.2). In age group 2, – "the middle-aged (>30 up to <50 years)" – were 20 persons with a mean age of 34.3 years (SD = 3.7) and in age group 3 – "the older ($\geq$50 years)"– 17 persons, with a mean age of 57.2 years, SD = 6.5).

With increasing age, participants showed a significantly lower technical self confidence (as measured by the short scale of Beier [27], $r = -.276$; $p < 0.01$; $F(2,88) = 5.6$; $p < 0.05$). Regarding the needs with respect to usable and easy to learn devices, no age effects were found (n.s.). Nearly all participants – independently from their age – expressed a specific claim for usable devices (from 48 points to be reached, all age groups ranged at about 44 points). Participants were not gratified for their efforts. Only a small fraction (2 %) had previous experience with smart textiles. 40 % had heard about the possibility to use smart textiles (mainly from the sports area). Mostly, participants were not aware that textiles could be also used as input devices for the home context.

3.2 Questionnaire

After a short demographics section in which age, gender and previous experience of participants with smart textiles were assessed, an introduction part was presented, in which smart textiles were explained as well as the idea to use smart textiles as input devices. A next section then addressed *perceived requirements (conditional acceptance criteria), but also benefits and barriers.* The items were based on previous studies in this context [6, 7] (Table 1).

Table 1. Items within the section "requirements, benefits and barriers". The items had to be answered on a 6-point Likert scale (1 = I do not at all agree; 6 = I completely agree).

Statements	
Positive	"These devices simplify my life."
	"I will gladly use these smart textiles."
Negative	"Such a device will complicate my life."
	"These devices will probably break easy."
	"I doubt such a device will work properly if hands are wet or dirty."
	"I'm afraid this device will be quickly stolen."
Conditionals	"The handling must be easy to learn."
	"The textiles have to last for a long term."
	"The handling has to be fun."
	"The textiles have to be stylish."
	"Using such a textile must not exhaust me."
	"The textiles and the functions they can control must be useful."

Furthermore, it was of interest if smart textiles would be evaluated differently, depending on different usage contexts and home spaces, in which the textiles could be used. We contrasted four different scenarios: kitchen, living room, bedroom, and clothing (i.e., wearables). For all these different scenarios, the following statements had to be evaluated (Table 2).

Table 2. Use of smart textiles in kitchen, living room, bedroom, and clothing. Items were answered on a 6-point Likert scale (1 = I do not at all agree; 6 = I completely agree).

Scenario statements
"I think the presented scenario make sense."
"I would like to buy such a textile."
"I'd be concerned that a casual touch is interpreted as an operating gesture."
"I believe the necessary gestures to control the device are easy to learn."
"I believe I'd enjoy the handling."
"My friends will envy me this textile."
"I believe gestures will be reliably recognized by the textile."
"I will be able to quickly perform learned gestures."
"I would be embarrassed to use the smart textile in front of others."
"I'd be afraid of inadvertently damaging the textile (e.g., by spilling drinks over it)"

4 Results

In order to analyze age effects, ANOVA respectively MANOVA procedures were run, with age as independent and acceptance items as dependent variables.

4.1 Conditional Acceptance Criteria, Benefits and Barriers

In a first step, participants evaluated the conditional requirements for an accepted use of smart textiles. In Fig. 2, descriptive outcomes are depicted. Items were arranged in three categories: Items that support the use (positive), items which express a negative attitude (negative) and those items which depict conditional acceptance, thus requirements which should be given in order to reach acceptance. From Fig. 2, two things are noteworthy:

(1) The agreements to the positive statements as well as the negative statements was much lower than the agreement to the conditionals, which should be given before participants would use smart textiles. Neither do participants fully agree to the positive items, according to which devices simplify life, nor do participants fully agree to the negative statements that were directed to an uncomfortable and bothersome use of smart textiles. When it comes to the conditional acceptance criteria, usability, usefulness, and ease of using the textiles are in the foreground for all participants. Interestingly, the design and the stylishness of the textiles are not so important.

(2) Age effects in the evaluation of the conditional acceptance criteria, but also the perceived benefits and barriers were mostly not present, revealing a quite unique view on smart textiles. Regarding the claim that the devices must last for a long time, a significant age effect was found ($F(2,89) = 4.9$; $p < .001$), with the younger participants agreeing to this claim much more strongly than the middle-aged and the older participants. A next age difference referred to the belief that those textile input devices might complicate the lives ($F(2,89) = 3.2$; $p < .001$), which is more frequently confirmed by older adults.

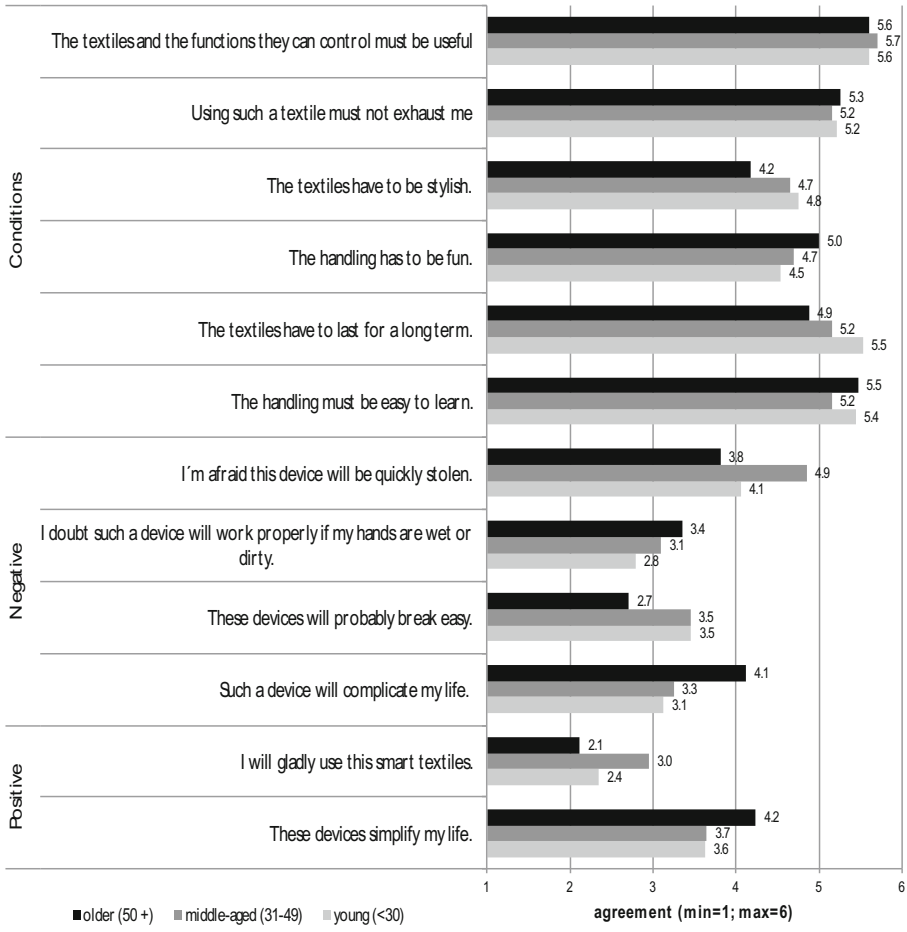

Fig. 2. Mean evaluations of requirements in the three age groups

4.2 Use of Smart Textiles in Different Home Scenarios

In a second step, participants evaluated the acceptance for the use of smart textiles in the kitchen, the living room, the bedroom as well as integrated into the clothes. It was analyzed if the perceived usefulness of smart textiles differs across scenarios, and, second, if age groups show a different evaluation.

In Table 3, descriptive outcomes (means, standard deviations) are given for all items, as well as the significance outcome for the main effect "scenarios" and "age". As can be seen from Table 3, the evaluation **across scenarios** differ in most of the cases. Textiles in the kitchen were perceived as less useful compared to the other scenarios ($F(3,83) = 7.5$; $p < .001$) and participants would not buy it for the use in the kitchen ($F(3,83) = 5.6$; $p < .001$).

Participants indicated to be to a lesser extent concerned that a casual touch would be interpreted as an operating gesture for clothes – while they are more concerned when

Table 3. Use of smart textiles in living room, kitchen, bedroom, and clothing. Items were answered on a 6-point Likert scale (1 = I do not at all agree; 6 = I completely agree).

Scenario Statements		*Scenarios (M, (SD))*				*Significance*
	Age-groups	*living room*	*kitchen*	*bedroom*	*clothes*	
"I think the presented scenario make sense."	Young (17-30)	3.3 (1.7)	2.4 (1.4)	3.3 (1.4)	3.9 (1.6)	*scenarios:* p<0.01; *age:* n.s.
	Middle (31-49)	3.1 (1.3)	2.8 (1.7)	3.1 (1.7)	4.0 (1.8)	
	old (50, +)	3.7 (1.7)	3.7 (1.8)	4.0 (1.6)	4.2 (1.6)	
"I would like to buy such a textile. "	Young (17-30)	3.1 (1.6)	2.5 (1.4)	3.1 (1.6)	3.3 (1.6)	*scenarios:* p<0.01; *age:* n.s.
	Middle (31-49)	2.8 (1.4)	2.4 (1.6)	2.5 (1.6)	3.5 (1.5)	
	old (50, +)	3.8 (1.7)	3.2 (1.7)	3.4 (1.6)	3.9 (1.5)	
"I´d be concerned that a casual touch would be interpreted as an operating gesture."	young(17-30)	4.8 (1.2)	4.8 (1.4)	5.1 (1.3)	3.3 (1.6)	*scenarios:* p<0.01; *age:* p<0.1
	middle(31-49)	4.2 (1.7)	4.1 (1.5)	4.6 (1.5)	3.1 (1.6)	
	old (50, +)	3.7 (1.6)	2.9 (1.6)	3.5 (2.0)	3.0 (1.7)	
"I believe the necessary gestures to control the device are easy to learn."	young(17-30)	4.9 (1.1)	4.7 (1.3)	4.7 (1.2)	4.8 (1.2)	*scenarios:* n.s. *age:* n.s.
	middle(31-49)	4.8 (1.4)	4.6 (1.3)	4.2 (1.4)	4.8 (1.5)	
	old (50, +)	4.9 (1.1)	5.1 (0.9)	5.2 (0.8)	5.3 (0.7)	
"I believe I´d enjoy the handling. "	young(17-30)	4.1 (1.5)	3.8 (1.5)	3.9 (1.5)	4.1 (1.5)	*scenarios:* p<0.01; *age:* n.s.
	middle(31-49)	4.0 (1.5)	3.8 (1.6)	3.6 (1.5)	4.3 (1.7)	
	old (50, +)	4.8 (1.6)	4.4 (1.7)	4.4 (1.4)	4.5 (1.4)	
"My friends will envy me this textile."	young(17-30)	3.6 (1.6)	2.9 (1.5)	3.3 (1.5)	3.5 (1.5)	*scenarios:* p<0.01; *age:* n.s.
	middle(31-49)	3.2 (1.5)	3.0 (1.7)	2.7 (1.6)	3.5 (1.5)	
	old (50, +)	3.1 (1.3)	3.0 (1.3)	2.8 (1.3)	3.6 (1.5)	
"I believe gestures will be reliably recognized by the textile."	young(17-30)	3.5 (1.5)	3.4 (1.5)	3.0 (1.4)	3.8 (1.8)	*scenarios:* p<0.05; *age:* p<0.01
	middle(31-49)	3.5 (1.4)	3.8 (1.6)	2.9 (1.1)	2.9 (1.7)	
	old (50, +)	4.3 (1.3)	4.5 (1.4)	4.5 (1.4)	2.6 (1.5)	
"I will be able to quickly perform learned gestures."	young(17-30)	5.1 (1.0)	5.0 (1.0)	5.0 (1.1)	3.7 (1.4)	*scenarios:* p<0.01; *age:* n.s.
	middle(31-49)	4.9 (1.1)	4.8 (1.2)	4.7 (1.3)	4.2 (1.3)	
	old (50, +)	5.3 (0.6)	5.2 (0.8)	5.1 (0.7)	4.6 (1.1)	
"I would be embarrassed to use the smart textile in front of others."	young(17-30)	1.9 (1.3)	2.0 (1.3)	1.9 (1.4)	1.8 (1.0)	*scenarios:* p<0.01; *age:* p<0.01
	middle(31-49)	1.4 (0.6)	1.4 (0.6)	1.8 (1.1)	2.2 (1.3)	
	old (50, +)	1.5 (0.9)	1.4 (0.6)	1.4 (0.6)	3.5 (1.9)	
"I´d be afraid of inadvertently damaging the textile (e.g., by spilling drinks over it)"	young(17-30)	4.3 (1.5)	4.8 (1.4)	3.9 (1.7)	4.7 (1.6)	*scenarios:* p<0.01; *age:* p<0.05
	middle(31-49)	3.1 (1.7)	3.3 (1.7)	2.7 (1.6)	5.3 (1.3)	
	old (50, +)	3.1 (1.6)	3.2 (1.5)	2.4 (1.1)	2.9 (2.1)	

the textiles are used in the different rooms ($F(3,83) = 7.2$; $p < .001$). In addition, the use of textiles in the kitchen and bedroom are perceived as less enjoyable ($F(3,87) = 4.8$; $p < .004$). Scenarios do also differ significantly regarding the belief that gestures will be reliably recognized by the textile ($F(3,88) = 3.2$; $p < .005$) and participants are differently convinced that they are able to quickly learn the gestures to control the smart textiles ($F(3,88) = 8.7$; $p < .001$). Age, in contrast, revealed to be a

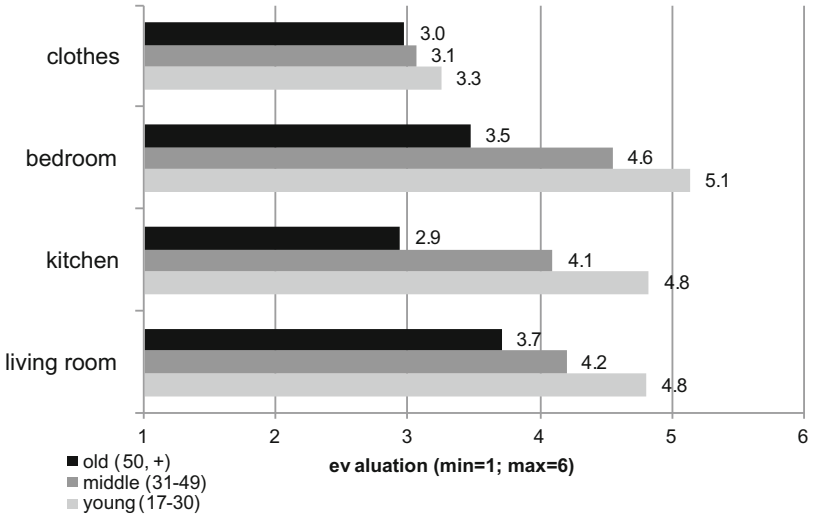

Fig. 3. Age differences: "I believe that the gestures will be reliably recognized by the textile"

not that decisive for acceptance. In contrast to younger age groups, older adults do not believe that the gestures will be reliably recognized by the textile ($F(3,87) = 3.3$; $p < .004$, Fig. 3).

On the other hand older adults are quite fearless that they inadvertently damage the textile ($F(3,87) = 4.8$; $p < .005$) when using it, in contrast to younger adults which are more afraid in this regard ($F(3,82) = 4.2$; $p < .005$, Fig. 4).

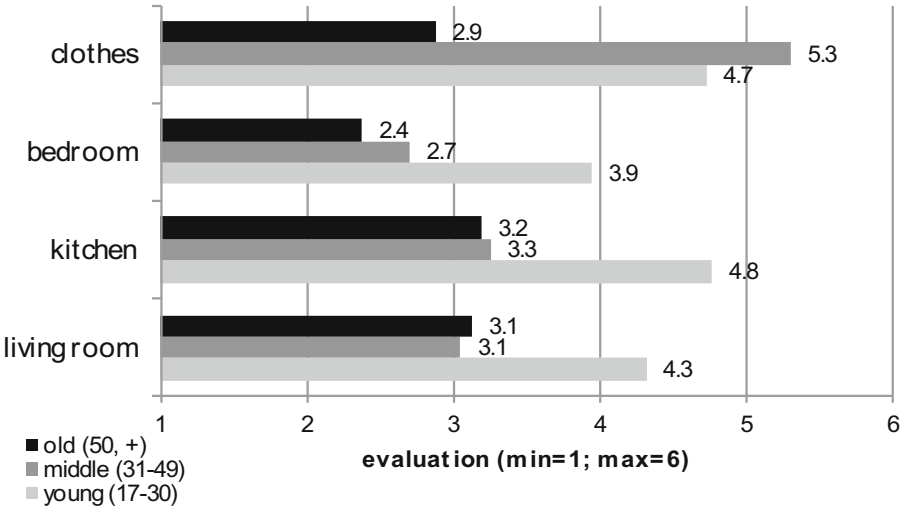

Fig. 4. Age differences for the item "I'd be afraid of inadvertently damaging the textile"

5 Discussion and Future Work

In this study, we examined the perceived suitability of smart textile input devices integrated into home environments. The exploratory approach had two major foci: One was directed to the understanding of users' attitudes towards the usage of textile input devices within different usage contexts, thereby differentiating the use of textiles in different rooms and clothing. The second focus addressed age as important user diversity factor. Generally, we revealed a basic openness to use novel devices, though the usage was connected to conditional acceptance factors. As such, usability, ease of use and high learnability of gestures to control the textiles were in the foreground. With respect to the different scenarios, textiles in the kitchen and bedroom are perceived as less enjoyable in contrast to textiles in the living room and textiles integrated in clothes. Age, in contrast, revealed to be a not that decisive for acceptance. Apparently, the use of novel technology at home is not impacted by age-related attitudes or values, but reflects a more generic claim for usable and easy to learn devices that is age-insensitive.

Based on the results presented above, we firmly believe that smart textile interaction surfaces in domestic environments will have a great potential to satisfy a wide range of people's needs. However, the road towards this vision is long and full of stones, especially if the people's perspective should be integrated and the design and development of should follow a participatory design approach. One should critically have in mind that the attitudes users report in questionnaires, might be quite artificial, at least as long as users do not have the chance to really interact with the textile technology and develop hands-on experience respecting the handling of smart textiles. Studies [28, 29] show that persons might overemphasize the fears and concerns against a novel technology (e.g., in terms of privacy and security violations), if evaluations exclusively only rely on the imagination of using it [30].

As the results here thus might lack mostly practical knowledge and factual validity, the next steps will be the identification of one or several concrete scenarios and an evaluation of these using focused technology acceptance models to reveal the key players that shape acceptance and rejection of theses innovative technologies. Furthermore, if specific use cases are identified and the interaction surfaces are developed, the potential users should be permanently included in the design. For example, using textile touch surfaces suggests to design novel interaction gestures and ordinary people should be integrated in the design and development of the gesture sets.

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