# Age, Gender, and Technology Attitude as Factors for Acceptance of Smart Interactive Textiles in Home Environments

## *Towards a Smart Textile Technology Acceptance Model*

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Abstract: Smart interactive textiles are the next frontier of ubiquitous computing and may serve as novel and accepted interfaces that go beyond conventional human-computer interaction. Apart from the technical perspective, it is important to understand if and under which conditions people adopt these technologies and which factors constitute perceived barriers of technology acceptance. In this work we examine people's attitudes towards smart textiles and their relationship to the intention to use these products in their home environment. This article provides a precise modeling of younger and older people in regard to expertise in interacting with technology, their desire to control and automate functions in their home environment, and the evaluation of a smart cushion for controlling the home environment, using the Smart Textile Technology Acceptance Model that is derived from the Unified Theory of Acceptance and Use of Technology 2 model. This model was applied for a specific smart textile product and the evaluation was focused on user-diversity, attitudes, and age. The article concludes with open research questions and guidelines for practitioners to leverage the benefits of smart textile user interfaces.

# 1 INTRODUCTION

25 years ago Marc Weiser and his team at Xerox Parc envisioned environments, in which smaller but increasingly powerful technology penetrates everyday objects and empowers us to seamlessly interact with our periphery (Weiser, 1991). He coined the term *calm computing* for technology which is in our focus when requested but dissolves into the background when not and which can provide more details, more information, or more capabilities and extends our peripheral reach (Weiser, 1991).

Today, we observe that a growing amount of devices are interconnected and beginning to form the Internet of Things (IoT) (Caceres and Friday, 2012). Smart devices reacting to the resident's presence, such as light bulbs, robotic vacuum cleaners, connected washing machines and refrigerators, or the heating, enter consumer households. However, conventional information and communication technology is usually packed in metal, glass, or plastics and are often perceived as artificial artifacts not harmonizing with our natural habitat.

While the inventions of transistors, microprocessors, advanced sensing, and actuating technology are rather new developments in human history, textiles have accompanied us since the dawn of mankind. Early traces of the use of textiles date back to 30.000 years B.C. (Robinson, 1970; Kvavadze et al., 2009) and have accompanied mankind since then. Textiles are usually perceived as warm, soft, smooth, and pleasurable. We do not only use them as clothes, but also for furniture, for example as bed linen, sofa coverings, curtains, or cushions.

We believe that these two branches of human development – ubiquitous computing and textiles – will eventually converge and that smart interactive textiles will be the next frontier of ubiquitous computing. However, from the observation of various technology adoption processes its is known that some technologies are adopted faster than others and that some technologies are never adopted at all. Technology acceptance research aims at understanding the factors which influence the likelihood of an adoption and weight the factors promoting or diminishing the acceptance of a product or service (Rogers, 2003).

Aging is one of the most important user factors that needs to be addressed in technology ac-



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ceptance research, as the demographic structure of many western societies is facing tremendous changes through progress in medicine, nutrition, hygiene, and a time of peace and prosperity (Giannakouris, 2008). More elderly expect to live with dignity and self-determination and they want to participate in the increasingly digitized society (Mollenkopf et al., 2000). Yet, numerous studies have identified that the elderly are often less literate in interacting with modern information and communication technology, such as computers (Selwyn et al., 2003), mobile phones and tablets (Arning and Ziefle, 2007), or even using ticket vending machines (Schreder et al., 2013).

In this article we combine these three lines – smart interactive textiles, user diversity, and technology acceptance research – and identify user and system factors which relate to the acceptance and likely use of a smart interactive textile. Specifically, we identify the factors which contribute to the acceptance of a smart textile cushion for controlling the home environment. We focus on age as a user factor in the design of our study and report the direct and indirect effects age might have on the acceptance of smart interactive textile user interfaces.

The article is structured as follows: After this introduction we present the current state of the art on smart interactive textiles, technology acceptance research, and research on acceptance of smart textiles in section 2. Section 3 presents our research questions and our research methodology. Section 4 presents the findings of our empirical study while section 5 discusses these findings and their implications for further design and development of smart interactive textiles. Section 6 concludes this article with a brief discussion of the limitations of this work and an outlook on further research questions.

# 2 STATE OF THE ART

This section presents an overview of smart interactive textiles in section 2.1, technology acceptance research in section 2.2, and technology acceptance research on smart interactive textiles in section 2.3.

## 2.1 Smart Interactive Textiles

In recent years, an increasing number of innovations was developed combining textiles with electronic interactive systems while concurrently different types and designs of input were discussed (Cherenack and van Pieterson, 2012).

One possible input option was evolved in the project *PinStripe*, in which parallel conductive threads were embroidered into clothes, for example in the sleeves of a t-shirt, a jacket, or a pants leg (Karrer et al., 2011). By pinching into the fabric with the fingers folds of varying size could be formed and rolled. The connections between the parallel conductive threads could then be interpreted as a two dimensional input device. A potential usage scenario was controlling music during working out. Rolling the fold moved the current playback position and the size of the fold determined the speed of the movement.

As a further example, Google's *Project Jacquard* (Poupyrev et al., 2016) built on this idea, integrating conductive yarns into fabrics and designing a series of garments with interactive areas woven into the garment. It is striking that smart textiles were mainly considered in terms of smart clothes for medical (e.g., monitoring of vital parameters) (Post et al., 2000; Axisa et al., 2003; Paradiso, 2003), sport (e.g., monitoring of sport performance), or leisure contexts (e.g., playing music or music control) (Helmer et al., 2009). Other possible interactive textiles (e.g., as part of furniture, such as carpets, blankets) have only been rarely considered so far.

A first technical approach and a recent application of smart textiles in the home environment is *Gardeene!* by (Heller et al., 2016). A conventional curtain is equipped with parallel conductive threads, allowing the system to sense either direct swipe gestures or swipe movements in near proximity of the curtain due to changes in the electromagnetic field. Intuitive swipe gestures are mapped to opening and closing the curtain. This approach could and will be transferred to other objects (e.g., blanket, cushion, sides of chairs).

## 2.2 Technology Acceptance

Two of the most influential models for predicting factors that promote or reduce acceptance are the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) and the Theory of Planned Behavior (TPB) (Ajzen, 1991). Both models postulate a strong relationship between an individual's *Intention* towards a specific behavior and his actual *Behavior*. This behavioral intention is governed by personal attitudes, subjective beliefs, and (in TPB) the individuals' self-efficacy towards the behavior.

Based on this strong relationship between intention towards a behavior and the actual behavior Davis' derived the well known Technology Acceptance Model (TAM) which assumes that *Perceived Usefulness* and *Perceived Ease of Use* govern the *Attitude Towards Using*, which on the other hand is closely related to *Intention to Use* (ITU) and later actual *Use* of a software (Davis, 1989). Despite its predictive power, this model was tailored for and evaluated with software for business contexts in the early '90's. Thus, more sophisticated models were developed over the time. A prominent example is Venkatesh's *Unified Theory of Acceptance and Use of Technology 2* (Venkatesh et al., 2012) which is specifically adjusted to capture the features that govern the acceptance of consumer products or services with voluntary usage. The model builds on the seven dimensions *Performance Expectancy* (PE), *Effort Expectancy* (EE), *Hedonic Motivation* (HM), *Social Influence* (SI), *Facilitating Conditions* (FC), *Price Value* (PV), and *Habit* (HB). The model was able to predict 74% of the variance of the intention to use a service and about 52% of the variance of the actual use after four months.

## 2.3 Acceptance and Interactive Textiles

The research landscape in the intersection of technology acceptance research and smart digital textiles is relatively sparse due to the novelty of this technology.

A first qualitative glimpse into the acceptance of smart interactive textiles was delivered by Holleis et al.. They investigated the suitability of different input modes for controlling a media player on different prototypical input devices. The study focused on the preferred design of the interaction surface (e.g., visible buttons, ornaments, invisible buttons) and accepted body locations for performing these gestures (e.g., hands, arms, legs, chest) (Holleis et al., 2008).

Within Google's *Project Jacquard* (Poupyrev et al., 2016) first usability evaluations on smart textile interfaces focused on the recognition rates of gestures (swipe right, swipe left, hold) under different conditions (sitting, walking, standing) using small interactive areas of a test jacket's sleeve. The overall recognition rate was 76,8% and varied significantly depending on the experimental conditions.

As wearables will probably be the first interactive textiles penetrating the market, a study examined the acceptance of wearable smart textiles in different usage contexts (van Heek et al., 2014). The study revealed that the evaluations were fundamentally different between the use of smart textiles in leisure contexts (i.e., sports) and medical contexts (i.e., monitoring vital parameters). The study also detected that factors of user diversity play a crucial role in the acceptance of wearable smart textiles, as the scenarios were evaluated differently depending on age, previous experiences, and the individual knowledge about the technology. Specifically, age had a strong influence on the perceived ease of using the technology as well as on the perceived functionality and reliability of the given product.

Furthermore, a more generic study on smart textile interfaces used a Conjoint-based approach to identify which product features are most important for the general acceptance of smart digital textiles (Hildebrandt et al., 2015). The most decisive attribute governing acceptance of smart textiles was the technical realization of these products. Specifically, users disliked noticeable electronics in the devices and instead desired a seamless integration into the fabric. The second most influential attribute was the room, in which the textile was used, showing that most users preferred smart textiles in the living room, whereas the use in the bedroom or kitchen was rather rejected. Although the functionality, i.e. what the smart textile should be able to do, was the third most decisive attribute, no clear preference regarding the three provided usage scenarios (i.e., health, media control, smart home) was articulated by the users. The least important attribute was wearability, and the participants of the study had a slight preference towards smart interactive textiles that are integrated into non-wearable devices (e.g., curtains, cushions, ...).

The comparison between wearable and non-wearable devices was also investigated in another study (Ziefle et al., 2014), in which user requirements for different types of smart textiles were analyzed in multiple contexts. First, the study revealed that the importance of product properties – such as look, durability, washability, price – do not differ significantly between smart textiles based cloth and furniture. For both, a pleasant-to-wear sensation or pleasant texture, durability, and a fashionable look are perceived as the most important evaluation criteria. Second, participants preferred table surfaces, chairs or sofas, and outerwear for integrating smart textile interaction surfaces, whereas smart carpets or curtains are perceived as the least favorable option. Third, the most favorable functions that should be controlled by the interaction surface were identified as changing the music, controlling interior lightning, or switching TV channels. Least favorable functions were controlling the heating and locking and unlocking smart locks.

These aspects were deepened in a second study, in which the motives, barriers, and conditions for using smart textiles were investigated, comparing different usage contexts (interactive textiles in bedroom, living room, kitchen, and interactive textiles integrated in clothes) (Ziefle et al., 2016). The results showed that the use of smart textiles was evaluated differently depending on the usage contexts: textiles in the kitchen and bedroom were perceived as less enjoyable compared with textiles in the living room and interactive textiles integrated in clothes. Furthermore, Ziefle et al. examined the influence of age on the acceptance and intention to use smart textiles. The results revealed significant age differences for single but not all acceptance factors (e.g., enjoying interacting with the device, reliable recognition of gestures); however, age revealed to be a less important predictor for acceptance. The study showed age differences regarding rather generic smart textiles and hence, it is questionable, how and to which extent a concrete, specific, and in the home environment integrated smart textile would be accepted by younger and older participants.

The presented studies detected that smart interactive textiles are predominantly accepted in the home environment and specifically the living room. However, previous research in the field of smart interactive textiles clearly focused on smart wearable textiles, while research on smart textiles in domestic environments was hardly investigated. Some studies showed that user diversity factors influence the acceptance of these technologies, for example, age, gender, and the attitude towards technology. Consequently, our overarching research question of this article is if these effects are also present for smart textile surfaces in domestic home environments and which evaluation dimensions govern their acceptance.

Based on first functional demonstrators and findings of a focus group we specified a smart cushion as an application scenario used in the remainder of this work. This smart cushion can be placed in the living room, for example on the sofa or armchair, and gestures on the cushion can be used to control music or light. The following section precisely describes our research methodology and the investigated variables.

# 3 METHODOLOGY

In the following section, the questionnaire design, applied statistical procedures, and characteristics of the sample are detailed. We chose a paper-and-pencil questionnaire for our study in order to reach especially older participants.

The goal of this study is to develop and evaluate a novel acceptance model for smart iterative textile surfaces (Smart Textile TAM, STTAM) and to understand the influence of age and other factors of user-diversity on the acceptance of a specific smart textiles. The study addresses three crucial research questions:

1. Which model-related dimensions are decisive for the acceptance of smart textile interfaces?
2. Which user factors influence the acceptance respectively behavioral intention to use smart textile interfaces?
3. To which extent do specific user factors, such as age and attitude towards technology, affect the acceptance and evaluation of a smart textile interface?

## 3.1 Questionnaire Design

Questionnaire items were adapted from the UTAUT 2 model to the context of smart textile interfaces and extended by constructs based on the findings of several focus group interviews with 4-6 people carried out prior to this study.

The first part of the questionnaire addressed participant's *demographic characteristics* (age, gender, educational level). Regarding user-specific aspects, we asked for participants' health status, such as chronic diseases and physical restrictions. In addition, the participant's previous experience with smart textiles was assessed (two items, $\alpha = .791$).

The questionnaire's second part asked for participants' *attitudes towards technology* (TECH), *textiles* (TEX), and *automation* (AUTO). The respective items were summed up and checked for item and scale reliability. The attitude towards technology was measured on a scale based on Karrer et al. which captures the four dimensions *Technical Enthusiasm* (EN), *Experience of Technical Competency* (COMP), and *Positive* (POS) as well as *Negative* (NEG) *Experience* with technology with three items for each dimension (Karrer et al., 2009) . Furthermore, the *Self-efficacy in Interacting with Technology* (SET) was measured on Beier's scale (Beier, 1999) with four items ($\alpha = .821$). According to Bandura, the domain specific self-efficacy refers to an individual's confidence to execute a specific behavior or to attain a specific goal (Bandura, 1982). It relates to an individual's choice of actions, the performance in these actions, as well as the endurance in these actions if difficulties emerge. Various studies found a tremendous influence of technical self-efficacy on interacting with computing technology (Selwyn et al., 2003; Arning and Ziefle, 2007; Schreder et al., 2013).

As no validated scale for measuring the *Attitude Towards Textiles* (TEX) exists, we built a new scale with four items based on previous findings from focus groups. This scale achieved a sufficiently high internal reliability for a newly developed scale ($\alpha = .658$). Furthermore, AUTO was queried using six items ($\alpha = .828$), which were also derived from the results of prior qualitative investigations.

Afterwards, the participants were asked to conceive a scenario, in which a cushion on the sofa in the living room functioned as a remote control for the domestic electronic devices light, music, and heating in the whole home environment. The participants were asked to imagine that electronic sensors were incorporated in the cushion, which were able to respond to different hand gestures. For instance, the cushion could be operated by stroking, kneading, grabbing, or rolling and twisting of folds.

Subsequent to the scenario, the participants were asked how they envisioned the cushion and how they would rate it and its possible functions. For this evaluation, an adapted acceptance model based on the UTAUT2-model was used (Venkatesh et al., 2012). Our *STTAM – Smart Textile Technology Acceptance Model* – incorporates the dimensions behavioral *Intention To Use* (ITU), *Performance Expectancy* (PE), *Effort Expectancy* (EE), *Hedonic Motivation* (HM), *Social Influence* (SI), *Facilitating Conditions* (FC), *Price Value* (PV), and *Habit* (HB) from UTAUT2. Furthermore and based on the results of previous qualitative studies, the model was supplemented by the dimensions *Washability* (WASH) and *Technical Conditions* (TC), capturing technical aspects, such as long durability or input efficiency. The participants had to evaluate the respective dimensions on three or four items each on a six-point Likert scale (0=strongly disagree; 5=strongly agree).

Finally, the participants were able to indicate which benefits and barriers of the smart cushion are most important to them and which household devices they would like to operate in their own home environment.

Completing the questionnaire took about 15 minutes. Data was collected in Germany in spring 2015 by using a paper-and-pencil questionnaire in order to address older people and to enable older people's participation in the questionnaire. Participation was voluntary and was not gratified.

## 3.2 Statistical Methods

All subjective measures were rated on six-point Likert scales. Data was analyzed using bi-variate correlations of model- and user-related factors, Pearson's $\chi^2$, uni- and multivariate analyses of variance (ANOVA/MANOVA) as well as linear regressions. The level of significance was set to $p = .05$. Spearman's $\rho$ was used for bivariate correlations and Pillai's $V$ was stated for the omnibus test of MANOVAs. The effect size was reported as partial $\eta^2$. The stepwise method was used in the multiple linear regression and models with low standardized $\beta$ were removed between the runs. Models with high variance inflation ($VIF \gg 1$) were excluded. The whiskers in the diagrams indicate the standard error.

Table 1: Inter-correlations of the five domains of technology attitude: Self-efficacy (SET), Enthusiasm (EN), Perceived Competency (COMP), Positive Attitude (POS), Negative Attitude (NEG). $^{\dagger}= p < .1$, $*= p < .05$, $**= p < .001$.

| | EN | COMP | POS | NEG |
|---|---|---|---|---|
| SET | .659** | .661** | .507** | -.305** |
| EN | — | .513** | .560** | -.198* |
| COMP | | — | .541** | -.316** |
| POS | | | — | -.266** |
| NEG | | | | — |

## 3.3 Description of the Sample

A total of n=136 people from a rural area volunteered to participate in our study and individually completed the paper-and-pencil questionnaire. 12 incomplete data sets were excluded, as only complete data sets could be used for further analyses.

The participants (n=124) were on average 49.5 years old ($SD = 16.2; min = 17; max = 86$) with 45.2% males and 54.8% females. 29.3% of the participants hold a secondary school certificate and 26.6% an university entrance diploma. Moreover, 27.4% completed junior high school, indicating the heterogeneity of the sample's educational level. Only a small percentage (14.8%) of the participants suffered from chronic diseases (e.g., diabetes, allergies). Additionally, 50.4% of the participants mentioned having pets (48.7% have no pets). None of these factors (educational level, health status, pets) correlated with age or gender.

The participants were asked for their technology attitude and experience in five dimensions. The correlation analysis in Table 1 illustrates that all five dimensions of attitude towards technology are closely interwoven. On average, the participants showed a positive *Perceived Competency* in interacting with technology ($M = 3.7; SD = 1.2; min = 0; max = 5$), a rather positive *Technical Self-efficacy* ($M = 2.9; SD = 1.2; min = 0; max = 5$), and a slightly positive perceived technology *Enthusiasm* ($M = 2.7; SD = 1.5; min = 0; max = 5$). The participants' evaluation of a *Positive Attitude Towards Technology* ($M = 3.3; SD = 1.0; min = 0; max = 5$) was on average affirmative, while a *Negative Attitude Towards Technology* ($M = 2.5; SD = 1.2; min = 0; max = 5$) was rated neutrally.

Moreover, participants stated having a positive *Attitude Towards Textiles* (TEX) ($M = 3.4; SD = 1.1; min = 0; max = 5$) and a slightly positive *Attitude Towards Automation* (AUTO) ($M = 2.9; SD = 1.6; min = 0; max = 5$). However, previous experience with smart textiles was very low ($M = 0.7; SD = 1.3; Min = 0; Max = 5$). A correlation analysis revealed significant relationships between gender (dummy coded as $0 = male, 1 = female$) and SET ($\rho = -.388, p < .01$, sig.), gender and TECH ($\rho = -.313; p < .05$, sig.), gender and TEX ($\rho = .245, p < .01$, sig.) and gender and AUTO ($\rho = -.255; p < .05$, sig.). Hence, women indicated to be less inclined to technology than men, whereas they were more inclined to textiles than men.

Concerning age, significant correlations were found for the relationships between age and SET ($\rho = -.328, p < .01$, sig.) as well as age and TECH ($\rho = -.278; p < .01$, sig.) with the elderly being less inclined to technology than younger participants. Moreover, age was not related to AUTO ($\rho = -.143, p = .113 > .05$, n.s.) and TEX ($\rho = .023, p = .803 > .05$, n.s.).

# 4 RESULTS

The results are presented as follows: first, the model-related factors determining the acceptance of a cushion as an example for smart textile interfaces are presented. Second, user factors which influence acceptance-relevant criteria are described and analyzed, applying a segmentation of user groups with regard to the *Attitude Towards Technology*. Afterwards, the results of the model-related factors are detailed for the segmented user groups.

## 4.1 Model Based Evaluation of the Smart Cushion

To understand which user factors and evaluation dimensions govern the intention to use the smart cushion, a correlation analysis is conducted. Table 2 illustrates that *all* considered dimensions of the STTAM are associated with the behavioral *Intention to Use* (ITU) a smart cushion.

In particular, HB, HM, and PE are strongly related to ITU. SI, FC, PV, and TC are also significant, though slightly less important, determinants for ITU and the acceptance of a smart cushion. In comparison, WASH and EE have a lower impact on ITU. To understand the key predictors for increased acceptance of a smart cushion in the home environment, a step-wise multiple regression analysis with the evaluation dimensions as independent variables and ITU as dependent variable is calculated. The calculation revealed three significant models for the whole sample. The first model predicts 83.5% (adj. $r^2 = .835$) variance of ITU and is based on UTAUT2's habit (HB) dimension: i.e., participant's behavioral intention to use a smart cushion is higher, if they can envision to use it regularly. The second model additionally contains *Hedonic Motivation* (HE) and explains +2.4% (adj. $r^2 = .859$) of the variance in ITU. The third and final model is based on *Habit*, *Hedonic Motivation*, and *Performance Expectancy* (PE) an adds another +0.3% (adj. $r^2 = .862$) explained variance. Table 3 presents the final regression model.

## 4.2 Influence of User Factors

Table 2 also presents the correlations between the user factors and the dimensions of the adapted UTAUT2 model. As it is shown, TECH and AUTO are associated with the intention to use: Participants being more inclined to technology and with higher wishes for automation tend to have a stronger behavioral intention to use smart textile interfaces. However, age ($\rho = -.044; p = .627 > .05$, n.s.), gender ($\rho = -.107; p = .240 > .05$, n.s.), and TEX ($\rho = .104; p = .254 > .05$, n.s.) are not related to the ITU. Furthermore, it is striking that gender is not related to any of the model's dimensions, while age is associated with EE. In addition, it is notable that TECH (which correlates with gender and age (see chapter 3.4)) is related to almost all dimensions except of PV ($\rho = .133; p = .121 > .05$, n.s.) and WASH ($\rho = .126; p = .149 > .05$, n.s.). As these correlative results lead to the assumption that the attitude towards technology influences the acceptance of and the *Intention to Use* smart textiles, a group segmentation was undertaken to analyze this relationship in depth.

## 4.3 Segmentation of User Groups by Attitude Towards Technology

To investigate the influence of attitude towards technology using factorial methods, we segmented the sample using a *k-means Cluster analysis* with two clusters and the five factors *Self-efficacy in Interacting with Technology* (SET), *Enthusiasm Towards Technology* (EN), *Positive Attitude Towards Technology* (POS), *Negative Attitude Towards Technology* (NEG), and *Perceived Competency in Interacting with Technology* (COMP).

The analysis converged after five iterations and yielded in two clearly separated clusters. The first cluster contains 74 participants. As Figure 1 illustrates, this group is characterized by a higher *Self-efficacy in Interacting with Technology*, higher *Perceived Competency*, higher *Enthusiasm Towards Technology*, and shows a more *Positive Attitude* as well as a lower *Negative Attitude Towards Technology*. In the following, this groups is referred to as *tech-savvy*. In contrast, the second cluster with 54

Table 2: Inter-correlations of user factors (bottom) and the product's evaluation (upper) on the Smart Textile TAM dimensions (PE = Performance Expectancy, HM = Hedonic Motivation, HB = Habit, EE = Effort Expectancy, SI = Social Influence, FC = Facilitating Conditions, PV = Price Value, WASH = Washability, TC = Technical Conditions, ITU = Intention To Use, TECH = Attitude Towards Technology, TEX = Affinity Towards Textiles, AUTO = Attitude Towards Home Automation). † = $p < .1$, * = $p < .05$, ** = $p < .001$.

| | PE | HM | HB | EE | SI | FC | PV | WASH | TC | ITU |
|---|---|---|---|---|---|---|---|---|---|---|
| PE | — | .689** | .755** | .348** | .553** | .520** | .335** | .351** | .367** | .764** |
| HM | | — | .765** | .313** | .534** | .577** | .373** | .335** | .549** | .791** |
| HB | | | — | .281** | .662** | .649** | .445** | .357** | .493** | .904** |
| EE | | | | — | .167† | .514** | | | | .207* |
| SI | | | | | — | .460** | .363** | .299** | .313** | .655** |
| FC | | | | | | — | .342** | .231* | .337** | .606** |
| PV | | | | | | | — | .246** | | .459** |
| WASH | | | | | | | | — | .182* | .304** |
| TC | | | | | | | | | — | .488** |
| Age | | | | -.236** | | | | | .176† | |
| Gender | | | | | | | | | | |
| TECH | .268** | .288** | .293** | .430** | .155† | .407** | | | .175† | .327** |
| TEX | | .302** | | .156† | | | | | .280** | |
| AUTO | .342** | .343** | .398** | .307** | .197* | .372** | .192* | | .198* | .491** |

Table 3: Linear regression table for Intention To Use (ITU) based on HE (Habit), Hedonic Motivation (HM), and Performance Expectancy (PE), $r^2_{adj.} = .862$.

| Model | B | SE B | β | T |
|---|---|---|---|---|
| (const) | -.614 | .129 | | -4.761 |
| HB | .664 | .070 | .633 | 9.542 |
| HM | .272 | .070 | .237 | 3.876 |
| PE | .136 | .068 | .114 | 2.015 |

participants is characterized by lower *Technical Self-efficacy*, lower *Perceived Competency*, lower *Enthusiasm*, lower *Positive Attitude*, and a more *Negative Attitude Towards Technology* than the first group. Hence, this second group is referred to as *tech-weary*.

As depicted in Figure 1, the cluster membership shows significant differences for all five considered dimensions of *Attitude Towards Technology* ($p < .001$).

Furthermore, Table 4 shows that the two technology groups are closely related to the factors gender, age, and *Attitude Towards Automation*. The *tech-savvy* group consists to a greater part of men and is comparatively younger than the *tech-weary* group. In addition, the *tech-weary* group indicated to have a more negative *Attitude Towards Automation* (AUTO) than the *tech-savvy* group.

## 4.4 Acceptance of Smart Textiles Depending on Technology Groups

Figure 2 illustrates the evaluation of the smart interactive cushion of both technology attitude clusters on

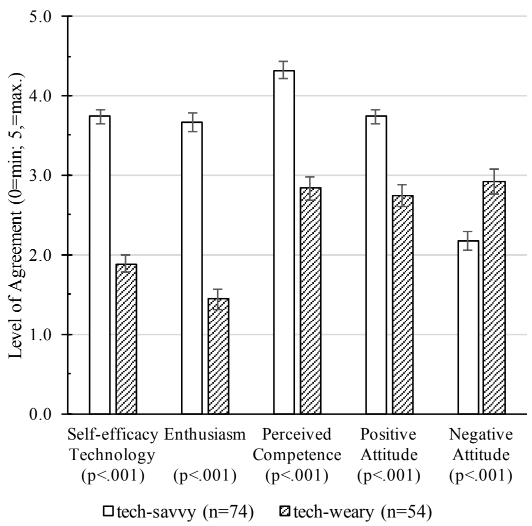


Figure 1: Differences in attitudes towards technology based on identified clusters (whiskers indicate the SE).

the Smart Textile TAM model's dimensions and the overall intention to use.

First of all, one-way repeated ANOVA analyzes revealed that the *tech-savvy* ($M = 2.2; SD = 1.5$) and the *tech-weary* ($M = 1.7; SD = 1.3$) group differed only slightly with respect to their *Intention to Use* (ITU) a smart cushion ($F(1,126) = 3.703, p = .057$). Both groups did not differ with regard to the dimensions *Performance Expectancy* (PE) ($F(1,127) = 2.812, p = .096$), *Social Influence* (SI) ($F(1,127) = 1.114, p = .293$), *Price Value* ($F(1,127) = 1.112, p = .294$), *Technical Conditions* (TC) ($F(1,123) = 0.342, p = .560$) and *Washabilty*

Table 4: Technology clusters (AUTO = Attitude Towards Home Automation, TEX = Affinity Towards Textiles).

| | tech-savvy | tech-weary | |
|---|---|---|---|
| Sex | 44m/29w | 14m/36w | $\chi^2 = 12.404$, $p < .001$ |
| Age | $44.1 \pm 15.1$ (17-78 years) | $55.0 \pm 16.2$ (23-86 years) | $F(1,119) = 13.528$, $p < .001$ |
| AUTO | $3.5 \pm 1.3$ | $2.0 \pm 1.6$ | $F(1,123) = 34.537$, $p < .001$ |
| TEX | $3.3 \pm 1.1$ | $3.5 \pm 1.2$ | $F(1,126) = 1.612$, $p = .207 > .05$ |

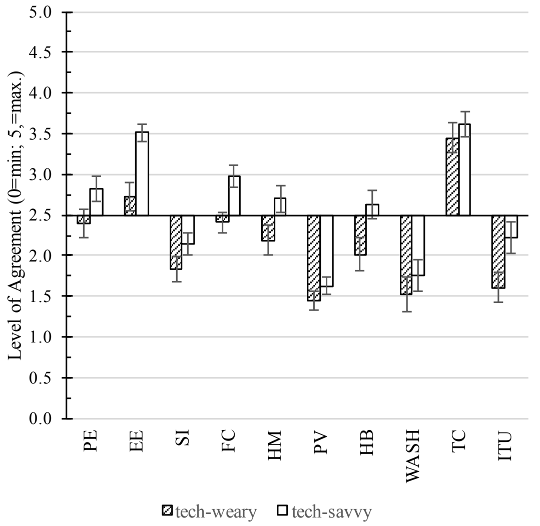


Figure 2: Evaluation of the smart cushion on the Smart Textile TAM dimensions by technology attitude clusters (whiskers indicate the SE).

(WASH) ($F(1,123) = 1.735, p = .190$). For all other dimensions, significant group differences were found. *Effort Expectancy* (EE) ($F(1,126) = 20.357, p < .001$) and *Facilitating Conditions* (FC) ($F(1,126) = 8.126, p < .001$) were significantly more important for the *tech-savvy* than for the *tech-weary* group. The same pattern applies to *Hedonic Motivation* (HM) ($F(1,126) = 3.905, p < .05$) and *Habit* (HB) ($F(1,127) = 4.732, p < .05$), which were slightly more important for the *tech-savvy* than for the *tech-weary* group.

# 5 DISCUSSION

In this article we investigated the acceptance of smart textiles as a medium for interacting with one's home environment, using a scenario with a smart cushion as an example. We measured the acceptance and the intention to use the device on a modified technology acceptance model that builds on Venkatesh et al.'s UTAUT2 model and incorporates the (perceived) washability and additional conditions as additional evaluation dimensions.

## 5.1 Appraisal of Smart Textile TAM (STTAM)

The results presented above and additionally illustrated in Figure 3 show that the intention to use a smart interactive textile is governed by all of the considered nine dimensions of the proposed Smart Textile TAM (STTAM). The results show that the proposed and adapted STTAM acceptance model operates and is applicable usefully for smart interactive textiles as all dimensions have an effect on the acceptance and the intention to use smart interactive textiles.

The multiple linear regression calculated in Section 4.1 also identified that habit, hedonic motivation, and performance expectancy are the three strongest predictors for the intention to use a smart cushion.

In the following the two newly added dimensions washability and technical conditionsand their effect on the intention to use of the STTAM are specifically highlighted. The added evaluation dimension washability was found to have an impact on the overall acceptance and intention to use the smart cushion in the home environment. Thus, we can conclude that developers of smart interactive textiles must consider and ensure that their products are washable and easy to clean. Additionally, feedback from our participants in prior qualitative and quantitative studies (novices as well as technological experts) showed the importance of washability issues as they were mentioned each time and in various contexts. Hence, the results suggest that the topic washability should also be addressed for marketing smart interactive textiles, e.g. by presenting a seal that assures that the product can be cleaned easily.

Furthermore, the second added evaluation dimension technical conditions was also found to have an impact on the acceptance of and intention to use the smart cushion in the home environment. The dimension's high assessment illustrated in Figure 2 indicated that our participants perceive the technical realization of the smart cushion (i.e., input efficiency, durability) as very important. However, the correlation with the overall intention to use is significantly lower than many of the other considered dimensions, such as the performance expectancy, or hedonic value

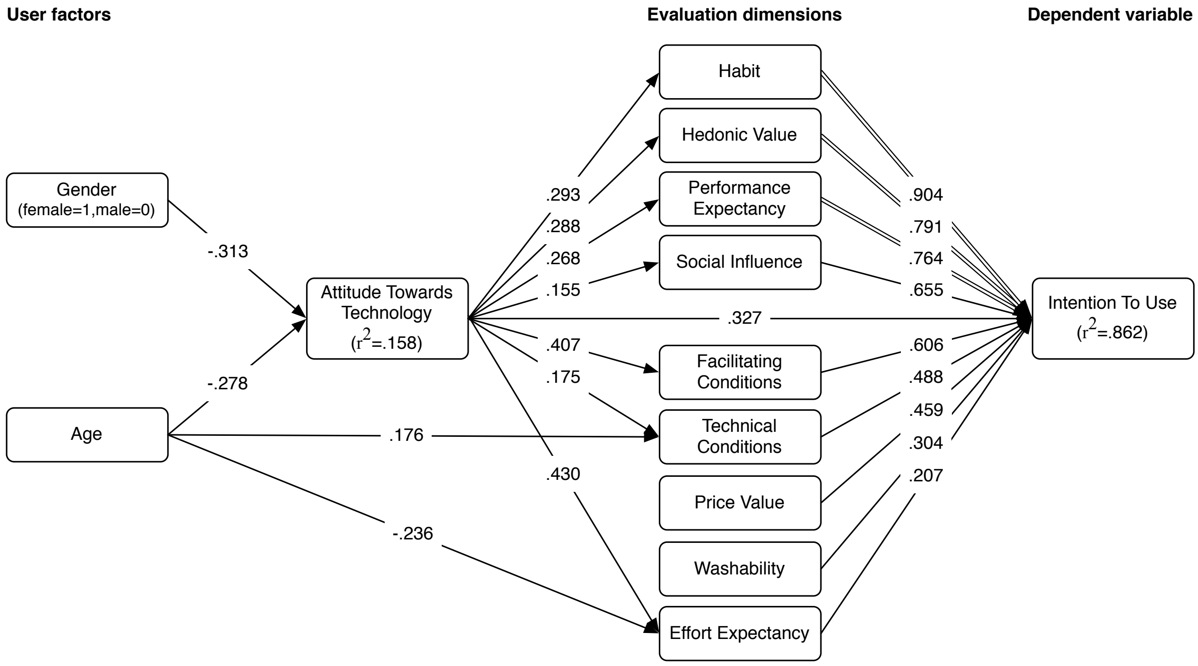


Figure 3: Representation of the essential results with user's factors on the left, evaluation dimensions in the middle, and intention to use on the right (solid lines = sig. relationships, doubled lines = variables from the regression).

of the product. Nevertheless, it would be valuable to address the technical realization in marketing and to put the technical functioning of the device and its longevity into the limelight.

## 5.2 Influence of User Factors

The study detected that age has a significant influence on the attitude towards technology. In our study, elderly persons reported a tremendously lower overall attitude towards technology and consistently lower scores for the five sub-dimensions self-efficacy in interacting with technology, perceived competency, positive and negative attitude towards technology, as well as enthusiasm towards technology. Likewise, women were also found to be less inclined towards technology than men. Both findings fit well into the research landscape, as they are common phenomenons in various technology acceptance research studies (Busch, 1995; Arning and Ziefle, 2007; Brauner et al., 2015).

The attitude towards automating processes at home (AUTO) – i.e., inclination towards home automation – is related to gender, but not to age. As AUTO was identified as the strongest user factor that governs the intention to use the smart cushion at home and even surpasses the influence of users' attitude to technology, this relationship should be investigated in depth in future studies.

The newly developed scale for capturing an individual's attitude towards textiles (TEX) achieved a sufficiently high internal reliability and was also related to the user factor gender, with women being more inclined towards textiles than men. More importantly, TEX is positively associated with the hedonic value attributed to the smart cushion. People with a higher attitude towards textiles found the smart interactive textile interface more pleasing, fun, and entertaining. Nevertheless, the results of our study also show that this positive influence of TEX on the hedonic value does not carry over to the overall intention to use the smart cushion. Therefore, further studies have to elaborate whether an high attitude towards textiles is decisive for adopting this novel input device or if the adoption is unrelated to this factor.

Astonishingly, the intention to use a smart cushion is neither related to age nor gender. Hence, we can conclude that smart interactive textile surfaces have the potential to serve as a novel and widely accepted interaction device. The only user factors which predict the likely use of smart interactive textile surfaces are the attitude towards technology and the desire to control and automate other devices at home.

However, age does directly affect the attitude towards automation and the attitude towards technology, which both have a strong influence on the model's evaluation dimensions and the overall intention to use. Hence, there is an indirect influence of age on the evaluation of the smart cushion and its likely adoption. Nevertheless, our study also revealed that age is not the only decisive factor for the attitude towards automation or attitude towards technology, for example, as there are tech-savvy elderly and tech-weary youngsters.

### 5.3 Deriving Guidelines

In the following, guidelines are suggested for the dimensions which are the strongest levers for increasing the acceptance and likely adoption of smart interactive textile surfaces in the home environment.

*Increase perceived habituation:* Bandura's self-efficacy (see Section 3.1, (Bandura, 1982)) theory offers several ideas to increase the perceived habituation of using these devices. For example, role models in ads can show how a smart interactive textile can be used in daily live to simplify certain activities. Also, friends and family members may persuade people to integrate these novel devices into their daily routine.

*Increase hedonic value:* To address the second strongest predictor – the hedonic value of the interactive textile surface – the design of these novel input devices should not only focus on simplistic usability measures, such as efficiency and effective according to ISO 9241/10 (DIN, 1998), but must also integrate the aesthetic and the perceived fun when using these devices (c.f., (Blythe et al., 2004)).

*Increase perceived benefits:* Eventually, the performance expectancy dimension refers to the perceived benefits of using the technology. For the smart cushion, the perceived benefit can be addressed by providing clear examples of what the smart cushion can be used for in his or her personal environment. For instance, by giving examples how the light of the living room can be adjusted to one's personal mood with an intuitive swipe gesture on the cushion or how music or television can be controlled using the cushion.

## 6 SUMMARY, LIMITATIONS AND OUTLOOK

The study gives first insights into the acceptance of smart interactive textiles in the home environment and on the impact of individual user factors on the acceptance taking a smart cushion as example. In the presented study, the participants evaluated a fictional cushion and therefore, their evaluation is primarily shaped by their beliefs, wishes, and fears than when a real cushion would have been evaluated. Obviously, a further study needs to address whether the identified acceptance patterns remain similar when a tangible and functional cushion is evaluated. This investigation would give us the opportunity to understand how scenario-based evaluations differ from the evaluation of concrete products.

Furthermore, the survey captures the snapshot of the user's evaluation at the time of the survey. We therefore cannot conclude with certainty that the identified predictors of the intention to use successfully predict the actual use of the product. Nevertheless, the underlying concepts of Fishbein and Ajzen's Theory of Reasoned Action (Ajzen, 1991; Fishbein and Ajzen, 1975), Davis' Technology Acceptance Model (Davis, 1989) (see Section 2.2) and Venkatesh's Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2012) have shown a very strong relationship between the usage intention and the actual later use. As it was mentioned before, the presented study was focused on a single smart interactive textile product – the cushion. Future studies will also need to focus on different products with different spectra of functions and characteristics to understand which determinants for later use are universal and which are tied to specific products. Our interdisciplinary research project on smart interactive textile surfaces has already developed a first demonstrator: The interactive curtain *Gardeen!* (Heller et al., 2016) presented in section 2.1. A first usability study found the demonstrator to be very intuitive and easy to use (high ease of use), though only a share attested the curtain a high usefulness. Other prototypical demonstrators are currently on a testing stage and will be evaluated in the near future.

In addition, there are some limitations with regard to the sample. This study's sample was rather small so that a replication of this study in a greater and more representative extent would be useful. If the study is replicated, it should be more balanced with regard to age: here, the study aimed to reach older participants leading to a comparatively "old" sample due to the paper-and-pencil questionnaire. This was useful to analyze older participants' needs and wishes towards smart interactive textiles. However, for future studies, a balanced age-distribution covering all age groups would be desirable.

Summarizing, the present study shows that smart interactive textiles can be a novel and suitable interaction device for older and younger people alike. Although an individual's attitude towards technology is a determinant for the projected acceptance, the relationship between age and attitude towards technology is measurable, yet not decisive. Furthermore, the presented guidelines enable designers and developers to build novel smart interactive textile products with an increased acceptance and higher likelihood of adoption and actual use. Therefore, this study contributed to the vision of calm and ubiquitous computing (Weiser, 1991), as it could identify the user factors that govern the acceptance of natural textile interaction devices in people's habitats, such as the smart cushion, armchairs, or other textile surfaces.

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