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User Experience of Wearable Technologies: A Comparative Analysis of Textile-Based and Accessory-Based Wearable Products

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Abstract: Wearable technology components have been integrated into accessories and then clothes over the evolutionary process. In the future, it is predicted that wearable technologies will be patchable and implantable. Despite progress in wearable technologies, there is an adaptation problem in wearable technologies. One of the most important reasons for this problem is the negative product experiences of the users. In this study, we investigated the user experiences of accessory-based and textile-based wearable technologies. Due to the temporality of the user experience, a mixed method was developed, including a survey for the expectations before use, a diary-interview for during use, and a semi-structured interview for after use. The data obtained with these methods were analyzed with SPSS and NVivo programs and the two different wearing-style experiences were compared. As a result of these analyses, it has been revealed that textile-based wearable technologies give a more positive experience during and after use and may be preferred over accessory-based wearable technologies in terms of wearability.

Keywords: accessory-based wearables; hedonic experience; pragmatic experience; textile-based wearables

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1. Introduction

The use of wearable technologies, along with the diversity of wearable products, continues to grow. Wearable technology products have so far found applications in monitoring and facilitating health, fitness and leisure activities, gaming, art, medicine, education, security, fashion, and entertainment and AR, VR, XR [1–3]. The research in wearable technology across many disciplines has led to many different definitions for wearable technologies. For example, Watkins and Dunne [4] (p. 123) define wearable technologies as "technology that is worn on the body. In theory, this could include any technology including the fibers and fabrics that are used in most clothing, but in practice it generally refers to electronic technology." Slade Shantz and Veillette [5] define wearable technologies as devices with sensors, screen, processor, memory, and software with algorithms for filtering, interpreting, organizing and storing collected raw data, that can connect to the Internet, and present the data to the user in real time or as a retrospective report. In other studies, wearable technologies are defined as devices that can monitor the physical activities (steps, calories, etc.) [6,7], physiological data (heart rate, body temperature, etc.) [8–10], clinical data [11–13], gesture detection [14,15], emotion recognition [16] of the user 24/7, collect and store, transmit this data while helping users perform many other useful micro-tasks such as checking incoming text messages and displaying urgent information [17–19]. Based on these definitions, we can briefly define wearable technologies as products that collect and process physiological data obtained from the user, and report this processed data back to the user via notification or through a network connection to another device or other actuators such as sound, light or vibration.

Wearable technology products can be positioned in many different parts of the body based on their functions and use contexts [20] in different forms such as portable personal accessories (e.g., glasses, contact lenses, watches), mobile devices (e.g., pocket step trackers), smart clothing and textiles and direct skin applications such as tattoos [21,22]. Thus, the level of integration between the body and the wearable technology product can range from technology carried on or suspended from the body as accessories, smart textiles and clothing to patchable and implantable products [23–26] (Figure 1).

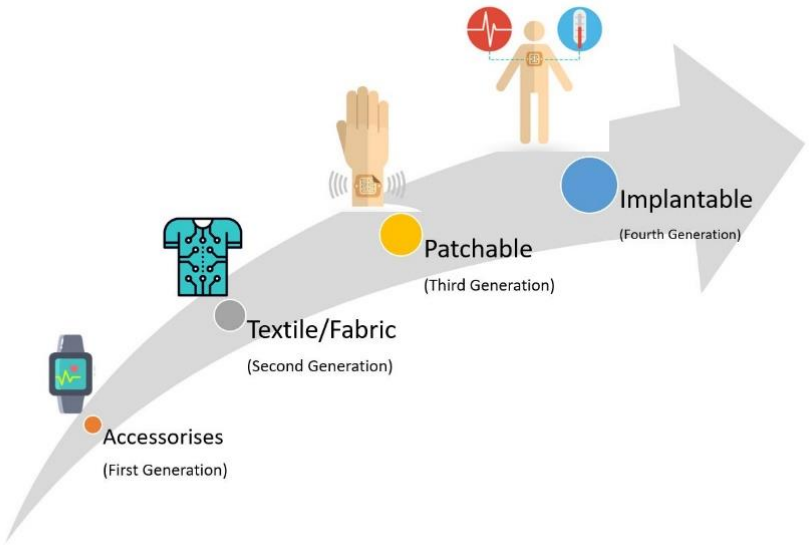


Figure 1. Level of integration with the body for wearable technology products.

The distinction between consumer wearables and medical wearables is increasingly blurred, so accessory and textile-based wearables have been widely adopted by users and the future is moving towards implantable and patchable wearable technologies [27]. In this study, the focus is on accessory-based and textile-based wearable technology products as they are accessible and commercialized for the end consumer. Even though many of these wearable technology products offer similar data, the way they are integrated to the body create significant differences in the design and development of these products. Differences in body sizes and shapes, mobility needs as well as the locations of sensing components on the body, donning and doffing, and care requirements lead to differences in user experience. This study explores accessory-based and textile-based wearable products comparatively with the goal to inform differences in user experiences due to their level of integration with the human body.

Forecasts predict rapid and strong growth as the wearables market is still far from reaching saturation. The increasing popularity of connected devices and the Internet of Things (IoT) and the rapid growth of the technologically literate population globally are projected to drive demand for wearable technology [28,29]. The rapid increase in the number of wearable technology users has also presented an interesting product adoption dilemma. Research showed that within six months of owning a fitness wearable technology product, approximately 30% of users stop using them [30]. A longitudinal study of Fitbit wrist bands found that 25% of participants quit the product after the first week and 50% after the second week [31]. Thus, long-term adoption of wearable technology products is a critical issue to be addressed. There are studies exploring the adoption problem of wearable technologies in different fields. Theoretical models such as the technology acceptance model (TAM), the unified theory of acceptance and use of technology (UTUAT) or the unified theory of acceptance and use of technology 2 (UTUAT2) are often used when researching the adoption of wearable technologies [32–37]. Apart from the applications of technology acceptance models, there are not many studies that approach the adoption of wearable technology products systematically from a user-experience perspective. Despite

the increasing scientific and industrial interest in the new user experiences provided by wearable technologies, few studies have been conducted to investigate the interactions between the human body and the wearable technology products that depend on it [38]. There exists no study investigating the user experience of textile-based and accessory based wearable technology products that offer entirely different wearing contexts. Filling this gap in the literature, this study explores the user experience of accessory-based and textile-based wearable technology products comparatively over time through surveys, diary-interviews and semi-structured interviews.

User Experience

User experience has been studied by different disciplines and thus various user-experience definitions have been made in the literature. The most referred-to user-experience definition was made by the International Organization for Standardization (ISO) as a "person's perceptions and responses that result from the use or anticipated use of a product, system or service." User experience includes users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors, and accomplishments that occur before, during and after interacting with a product. User, design (product, system, service) and context of use are the three main factors of user experience [2,39–41].

Through an in-depth review of the literature in user experience, the framework displayed in Figure 2 was developed to guide this study. This framework demonstrates a pragmatic and hedonic analysis of the change in user experience over time depending on the context of use of wearable technology products.

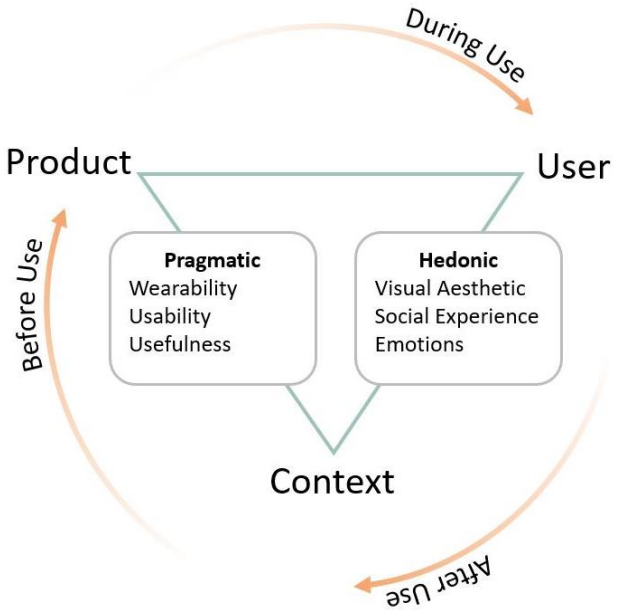


Figure 2. User-experience framework of the study.

In this study, we approach the user experience of wearable technology products in the sports/fitness context since we determined the highest number of commercially available wearable technology products clustered in this category through an in-depth analysis of the market. Figure 3 displays the categorization of the commercially available wearable technology products used in the sport/fitness field on the market, based on our comprehensive market analysis. The identified wearable technology products are categorized according to their position worn on the body and accessory and textile-based structures. The analysis yielded an accessory-based chest band and a textile-based smart T-shirt that offer the same functionality while worn on the same part of the body. Thus, this study employed these two products to comparatively explore the user experience.

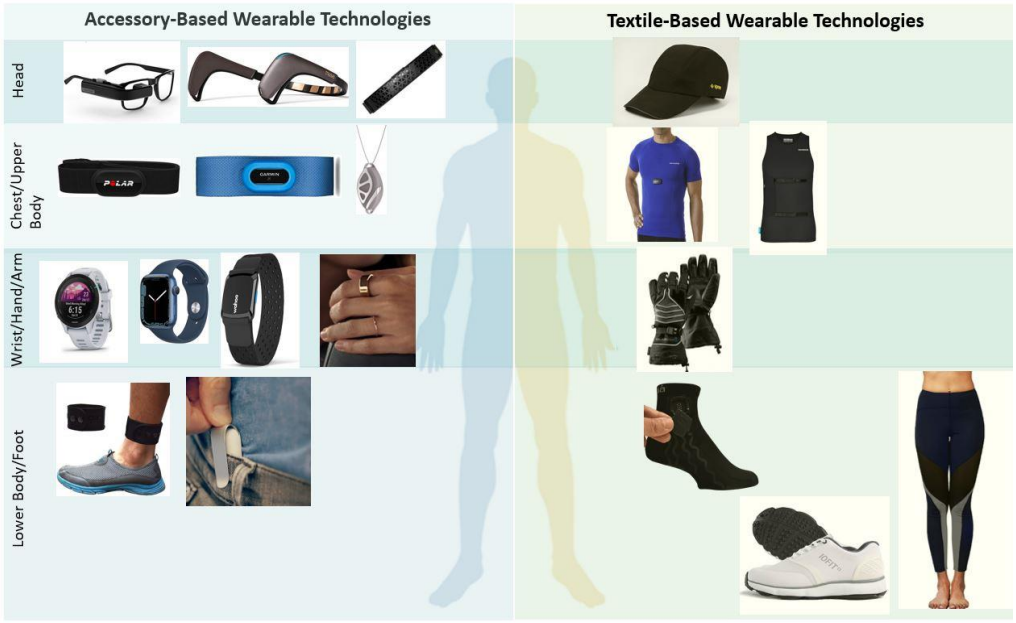


Figure 3. Market research for accessory-based and textile-based wearable technologies.

Another important factor affecting the user experience is time. User experience changes and evolves over time. We need information about long-term user experience, as it is not very reliable to evaluate an immediate user experience to predict real-life user experience or evaluate the success of a product. Many studies have been conducted and models have been developed examining long-term user experience [42–48]. Moellendorff et al. [49] emphasized a longitudinal approach when developing a model for user experience, and distinguished between micro- (one hour use), meso- (a few weeks of use) and macro- (years of use) perspectives on the role of time in user experience. Similarly, Roto et al. [50] defined four types of user experience over time; expected user experience (before use), immediate user experience (during use), episodic user experience (after use), and cumulative user experience (multiple-use cases over time). In this study, the user experiences of two different wearable products with the same function, a chest band and a smart T-shirt are explored from the perspective of user expectations before use and experiences during and after use.

Hassenzahl [51] suggested the pragmatic and hedonic quality model evaluating user experience. Pragmatic qualities are the features that enable the product's relevant functionality (i.e., utility) and ways to use this functionality (i.e., usability). Hedonic quality, on the other hand, refers to the features that enable the user to obtain positive emotional results related to the psychological state of the user. Based on the pragmatic and hedonic model, we determined three pragmatic (wearability, usability, and usefulness) and three hedonic (visual aesthetic, social experience, and emotions) categories for wearable technologies as seen in Figure 2. Pragmatic qualities describe the instrumental attributes such as thermal comfort, fit, ease of use, performance, and understandability while hedonic attributes express the subjective attributes, such as perceived aesthetics, social experience and emotions. Another reason for evaluating the pragmatic and hedonic aspects of the products separately is that as the user–product relationship develops over time, the hedonic aspects start to gain more importance in evaluating the user experience [52]. For this reason, it is also important to examine user experience in the long-term.

Finally, according to Venkatesh and Goyale [53], both positive and negative confirmation of expectations have effects on the user's adoption of the product. For this reason, both positive and negative experiences should be investigated in terms of adopting a product and meeting the expectations of the user. Therefore, understanding a product's user experience requires a thorough examination of the positive or negative user experience [54]. We studied both the positive and negative user experiences of the chosen wearable technology

products that display the same functions with different wearability on the same body part, an HRM (heart rate monitor) chest band and a smart T-shirt, from a pragmatic and hedonic perspective over time in the context of sports performance and motivation.

2. Methods

Quantitative and qualitative methods were employed in order to examine how user experiences regarding the accessory and textile-based wearable technology products evolved over time in the context of sports performance and motivation.

First, market research was conducted to determine the wearable technology products commercially available as introduced previously under the user experience section. As a result of this market research, wearable technology products that have the same tracking functions, worn on similar body parts but in different ways (clothing versus accessory) were determined as the Polar chest band, and Sensoria smart T-shirt and bra. These products are devices for measuring the heart rate of users (HRM). Users use these products to track their fitness activities. Both of the chosen products have Bluetooth connection and work with different applications and operating systems on all different types of smart phones. Concerning these products, the Polar chest band is a unisex product; the Sensoria brand products are not unisex as they are textile-based and they are available as a sports bra for women and a T-shirt for men. Care was also taken to ensure that the products identified are products that users can easily find and purchase. Wearable technology products that are not widely available were avoided.

The study was carried out in three phases to study the user experience before, during and after use, based on the approval of the ethical review board (ERB No: 23909). The first phase included a survey to understand the hedonic and pragmatic expectations of the wearable technology products for fitness before use. This survey also enabled the identification of users who will participate in the other phases of the study. In the second phase, the diary-interview method was used to investigate the positive and negative experiences of the users during use for two weeks with the chest band and smart T-shirt individually. In the third phase, semi-structured interviews were conducted to explore reflections about the positive and negative experiences after the use of each wearable technology product. All methods and analysis applied throughout the study are shown in the Figure 4.

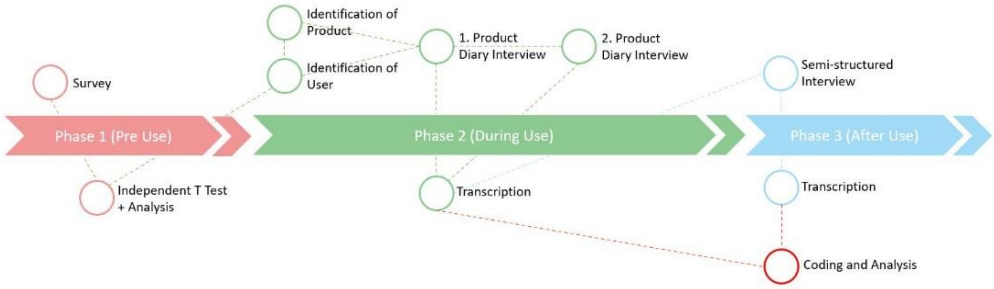


Figure 4. Summary of the methodology.

2.1. Phase 1: Survey

An online survey was conducted to determine the hedonic and pragmatic expectations of the users from wearable technology products in general. In addition, whether or not there is a significant difference between the expectations of individuals who previously used wearable technology products and those who did not use them, as well as those who exercise regularly and who do not, was investigated. Mahlke and Thüring [55] created a user-experience model examining user experience as instrumental and non-instrumental product features similar to Hassenzahl's pragmatic and hedonic approach. Minge et al. [56] developed the modular assessment of key components of user experience (meCUE) to measure user experience based on the CUE (component of user experience) model. Our survey was prepared on the basis of the modular structure of the meCUE survey model

to measure user expectations of wearable technology products. The survey consisted of three parts: (1) demographic questions, (2) wearable technology use and sporting activity habits, (3) expectations of users from wearable technology products. The third part consisted of a total of 41 questions under 6 main headings (wearability, usability, usefulness, visual aesthetic, status, and emotions) using a 7-point Likert type scale questions. (1—not important, 4—no matter, 7—very important).

Out of a total of 399 survey responses, 374 participants who completed the survey fully were evaluated. Among the participants included in this evaluation, 42.9% (158) were female and 51.9% (214) were male, and the average age was approximately 36, ranging from 18 to 65 years. The 374 responses evaluated were analyzed using the SPSS software. Firstly, Cronbach Alpha Test was applied for the consistency of the answers. Afterwards, independent t-test was applied to investigate whether there was a significant difference between the expectations for wearable technologies among individuals who have used and have not used these products before. Independent t-test was also applied to investigate differences between individuals who exercise regularly and those who do not.

2.2. Phase 2: Diary–Interview

In this phase, the diary-interview method was employed to investigate the positive and negative experiences of the users with the chest band and smart T-shirt during the use period of two weeks. The diary-interview method requires the participants keep a diary, then these diary records are examined and follow-up interviews about the collected data are conducted with the participants [57,58]. The follow-up interview provides an important opportunity for the researcher to evaluate the diary records that the participants had difficulty in expressing or those that could be misinterpreted. Because the follow-up provided a prolonged engagement, it allowed us to understand the information on the purpose the products were used for and how the duration and frequency of use were verified. So, prolonged engagement is the best way to ensure credibility in a qualitative study [59]. Furthermore, diary studies are advantageous as participants report their experiences according to their own context and time [60]. Therefore, this method does not affect the user's experience.

A total of 10 users, 5 women and 5 men, participated in the diary-interview for 2 weeks. Participants in this phase of the study were recruited from the survey respondents by using a snowball sampling method. Inclusion criteria were regular participation in fitness activities for 3–4 days a week, owning a smart phone, and wearing a medium size T-shirt. All participants were informed about the study protocol and a written consent form was obtained. Participants were asked to use the chest band and the smart T-shirt taking random turns for one week (3–4 times a week) during their daily exercise routines. Participants were expected to connect the provided wearable technology products to their smart phones and monitor the obtained data. After each use, participants were asked to convey their positive and negative experiences with each product about their wearability, usability, usefulness, emotions, social experiences, and visual aesthetics either as voice or text messages. The recorded daily experiences were examined by the researchers and follow-up interviews were conducted for the missing or incomprehensible parts.

The qualitative data obtained as a result of the diary-interview method were analyzed using the NVivo software. Users' audio and text diaries and interviews were primarily transcribed. Afterwards, these transcripts were coded with the help of NVivo software. A total of 46 codes were created which were categorized under the titles of wearability, usability, usefulness, emotions, social experiences, and visual aesthetics, and classified as positive and negative experiences for the chest band and the smart T-Shirt.

2.3. Phase 3: Semi-Structured Interview

The semi-structured interview method was employed in order to probe deeper into the positive and negative user experiences of accessory-based and textile-based wearable technologies after the use period. In this interview, their experiences over six main categories

(wearability, usability, usefulness, visual aesthetic, status, and emotions) were questioned and they were expected to compare the two products. Participants were then asked to indicate their expectations from a wearable technology product based on the experiences they engaged in. The data obtained from the interviews were analyzed using the NVivo software in the same way as in phase 2.

3. Results and Discussion

3.1. Survey Results: Pre-Use Experience and Expectations of Wearable Technology Products

The survey questioned pre-use expectations and experiences of the wearable technologies, and exercise habits of the participants. Of the participants, 72.5% stated that they exercised, and 27.5% stated that they did not exercise at all. Participants who exercised mostly did walking, jogging, cycling, fitness, and swimming sports. Sixty percent of the participants who did exercise stated that they exercised regularly, while 40% did not exercise regularly. In addition, 15% of the participants who exercised regularly were licensed athletes. As for the use of wearable technology, 66% of the participants had never used wearable technology before, while 34% had used wearable technology. Of the participants who had used wearable technology, 51% used it every day, 10% used it 5–6 days a week, 20% used it 3–4 days a week. Contrary to the studies stating that the rate of abandonment of wearable technology products is high [30,31,61], 55% of these participants have been using wearable technology products for more than 12 months. Thirteen percent stated that they had been using it for 6–12 months, and 8% said that they had stopped using it. The majority of the participants using wearable technology products used smart watches or smart bracelets. It can be interpreted that the use of these preferred wearable technology products also as daily accessories by the users had an effect on these rates.

The expectations of the users were measured using 7-point Likert scale where 7 is very important and 1 is very unimportant. Descriptive statistical analysis of the data was carried out with SPSS software. Wearability, usability, usefulness, visual aesthetic, social experiences, and emotions were evaluated, as shown in Table 1.

The survey results show that the pragmatic expectations of the users are more important than the hedonic expectations. When we examined it categorically, the most important feature in wearable technologies for users in pragmatic expectations was the usability (M = 6.19) of the product, followed by expectations on wearability (M = 6.04) and usefulness (M = 6.01). In the usability category, the battery life (M = 6.45) of a wearable technology product was the most important feature for users, while in the wearability category the most important feature was mobility (M = 6.32). In the usefulness category, users gave the highest score for the wearable technology product being suitable for its intended use (M = 6.22). While emotions (M = 5.68) were the highest value in the ranking of users' hedonic expectations, it was determined that users had lower expectations in the social experiences (M = 4.83) and visual aesthetics (M = 4.73) categories. The feeling of safety (M = 5.93) of the product used was the highest value in the category of emotions, while the personalization (M = 5.38) of the wearable technology product was the highest value of the social experience, the high quality look (M = 5.44) of the product was the highest expectation in the visual aesthetics category.

When users' pragmatic, hedonic expectations from wearable technologies are met, it leads to higher satisfaction levels [62]. Another study stated that in addition to usability, wearability factors such as discomfort, is more decisive for the user [63]. Our findings also indicated that expectations on usability and wearability were the most important parameters for user satisfaction and the product acceptance process for wearable technologies. On the other hand, hedonic values increased user loyalty more than satisfaction alone and created pleasure [64]. Although it was determined in our study that users' hedonic expectations had a lower ratio than pragmatic expectations, it is known that the hedonic aspects of an experience increase over time. Therefore, it is important to investigate hedonic values during and after use.

Table 1. User expectation analysis.

			N	Mean	Std. Deviation	Variance
Pragmatic	Wearability	No harm to body	371	6.429	1.227	1.505
		Mobility	370	6. 324	1.270	1.613
		Comfort	374	6.267	1.363	1.859
		Thermal comfort	371	6.267	1.297	1.683
		Easy cleaning	373	6.257	1.250	1.563
		Easy donning, doffing	374	6.246	1.272	1.618
		Fit	371	6.151	1.315	1.729
		Heavy–size	370	6.049	1.382	1.911
		Sensory adaptation	371	5.722	1.493	2.228
		Accessory	374	5.393	1.532	2.346
		Cloth	369	5.344	1.496	2.237
	Usability	Battery life	370	6.454	1.166	1.360
		Data accuracy	372	6.341	1.269	1.611
		Product performance	369	6.282	1.223	1.496
		Response time	374	6.235	1.238	1.532
		Self-use	373	6.188	1.335	1.782
		Easy use	372	6.121	1.269	1.611
		Understandable	372	6.067	1.298	1.685
		Easy to learn	371	6.065	1.338	1.790
		Feedback	372	6.048	1.260	1.588
	Usefulness	Long time use	371	6.272	1.167	1.361
		Intended use	368	6.223	1.239	1.536
		User performance	374	5.794	1.335	1.783
		User motivation	374	5.767	1.371	1.879
Hedonic	Visual Aesthetic	High-quality looking	374	5.447	1.579	2.494
		Creativity looking	373	5.335	1.621	2.627
		Fashionable looking	373	5.215	1.629	2.653
		Innovative looking	371	5.043	1.735	3.009
		Impressive looking	373	4.713	1.771	3.135
		Technological looking	370	4.695	1.772	3.140
		Flashy looking	374	4.072	1.868	3.488
		Expensive looking	372	3.336	1.842	3.394
	Emotions	Safety	373	5.930	1.459	2.130
		Good	370	5.773	1.510	2.279
		Happy	372	5.583	1.631	2.659
		Joy	373	5.421	1.622	2.631
		Cool	374	5.185	1.697	2.880
	Social Experience	Personalization	371	5.385	1.627	2.648
		Makes feel different, unique	374	4.997	1.766	3.118
		Attracting the attention of other people	374	4.131	1.876	3.519

In order to determine user experience in the during and after use phases, normality tests were carried out first, and an independent t-test was performed afterwards. There was no significant difference between the expectations of participants who had used wearable technology before (5.67, sd = 1.06) and participants who had not use wearable technology before (5.53, sd = 1.04) (t (372) =1252, p = 0.211). At the same time, comparison of the expectations of users who exercise regularly (5.61, sd = 1.066) and users who do not exercise regularly (5.43, sd = 1.197) had no significant difference (t (263) =1287, p = 0.199). As stated in the Methods Section, the results of the survey enabled us to identify the participants who would be included in the diary-interviews focused on the chest band and the smart T-shirt use experience. According to these results, we decided that regardless of the prior wearable technology experience, the diary-interview participants should still meet the inclusion criteria of regular exercise.

3.2. Diary-Interview and Semi-Structured Interview Results: Wearable Technology User Experience

The purpose of the analysis performed in this phase was to first compare the accessory-based wearable technology (chest band) and the textile-based wearable technology (T-shirt) in terms of positive and negative experiences. Next, the change in these compared experiences over time was examined after the active use period. A code diagram was created with the findings obtained from the diary-interviews during use and from the semi-structured interviews after use from 10 participants. Twenty-four positive experience and twenty-three negative experience codes were developed for the chest band and the T-Shirt together. These codes were also grouped under six main categories. The frequency values of these codes and sample quotes of experiences are shown in Table 2.

Table 2. Coding of user experience as positive and negative experiences in 6 categories in the pragmatic and hedonic framework. (The abbreviations of these codes are used in the graphics).

	Category	Code	Code Sequence	Subcode	Frequency (Chest Band/T-Shirt)	Example Experience
Pragmatic	Wearability	Fit	(W1)	Posture-positive	0/4	My favorite feature was that it kept my body upright
				Comfort-positive	0/4	I can say that it makes you comfortable while exercising.
				Comfort-negative	5/0	It is something that is squeezing, so I cannot say that it is very comfortable.
				Structure of the product-positive	2/12	The T-shirt is elastic, it is very comfortable . . .
				Structure of the product-negative	10/11	It would be better if the throat part were a little wider so that it does not tighten.
				Movement on body-positive	1/1	Does not slip when brought to the appropriate tightness.
				Movement on body-negative	15/0	Even while walking, I was checking whether it fell or not.
		Donning, doffing	(W2)	Positive	9/6	T-shirt is much easier than chest band as we are used to it.
				Negative	5/10	On the first day, it was difficult to put on and take off, although the product fit my size. I got help from my wife in removing it.
		Tactile comfort	(W3)	Positive	1/0	There is no harm, no allergic reaction, etc., nothing happened. Very healthy products.
				Negative	21/0	However, the chest band, in contrast, was making marks when I sweat. It could be an irritation because it was involuntary play.
		Mobility	(W4)	Positive	1/10	It made me feel comfortable both while doing sports and doing the moves.
				Negative	11/1	I think it is designed to be a nuisance because it feels like someone is hugging me from behind.
		Thermal comfort	(W5)	Positive	1/14	In terms of thermal, sweating, and cold, the T-shirt was very good. It never sweated.
				Negative	9/2	It was uncomfortable because the chest band made it sweat more.
		Sensory adaptation	(W6)	Positive	0/5	I started to not feel the product while running, but the other product was always on my mind.
				Negative	14/0	You feel the presence of the product on the band, this feeling was not created in a positive sense, but rather in a negative sense.
	Usability	Understandable	(Ub1)	Positive	4/2	I was able to understand its features, but more features can be added.
				Negative	1/0	I could not quite figure out where to put it.

Table 2. *Cont.*

	Category	Code	Code Sequence	Subcode	Frequency (Chest Band/T-Shirt)	Example Experience
		Connection	(Ub2)	Positive	13/3	However, the connection of the device with the phone was very quick. It did not bother me at all.
				Negative	0/10	I could not find the application, I tried several applications on the box, but I could not establish a connection between the device and the phone.
		Care	(Ub3)	Positive	4/2	The T-shirt is machine washable and its texture has not deteriorated.
				Negative	3/1	As for cleaning, I clean the T-shirt in the machine, I had to clean the band by hand, so it is much easier to clean the T-shirt.
		Feedback	(Ub4)	Negative	3/3	Apart from that, an indicator light should come on to show that it is connected with the phone.
		Data Exchange	(Ub5)	Positive	4/2	Afterwards, I followed the features of this product while walking, and I did not have any problems.
				Negative	3/5	Although I was not able to measure my performance due to technical glitches.
		Data accuracy	(Ub6)	Positive	7/6	So, the data came true. For some reason, I trusted them more.
				Negative	0/1	Therefore, I could not be sure that the product gave full and correct results.
	Usefulness	Motivation	(Uf1)	Positive	15/23	That is why I felt active, I felt more vigorous. Thanks to these features, it encourages sports.
				Negative	4/0	Since it is not very useful, it does not provide a positive motivation.
		Performance	(Uf2)	Positive	4/10	We can say that the T-shirt increased my motivation and performance more.
				Negative	4/0	It did not increase my performance, on the contrary, I restricted myself to see if it would fall out.
		Intended use	(Ubf3)	Positive	4/7	If you are testing it for the purpose of use, I think the necessary products are already on the market.
Hedonic	Visual aesthetic	Size-Form	(V1)	Positive	1/0	It is good that it is small in terms of view.
				Negative	10/12	If the device was a little smaller, it would look more stylish and technological.
		Good Looking	(V2)	Positive	14/18	I think the visual of the product is aesthetic; it has a stylish design.
				Negative	8/4	In terms of visual aesthetics, being outside of the apparatus does not provide a pleasant appearance.
		Color	(V3)	Positive	2/4	I liked that the color of the product is the same as the sensor in the product. I might not like it if they were two different colors.
				Negative	6/3	If there is only one color as a color, a vivid color would be preferred.
		Quality Look	(V4)	Positive	2/5	The product looks stylish and high quality.
	Social Experience	Social Experience	(S1)	Positive	9/19	I would recommend it to someone else because it is encouraging and looks good.
				Negative	6/0	Since it is already in contact with the skin, people cannot see it. This is also a disadvantage. If it shows on the outside, it can be a kind of advertising element.
	Emotions	Emotions	(E1)	Positive	4/14	I felt happier, more alive, better, more secure while wearing the T-shirt compared to the chest band.
				Negative	6/1	I am afraid of using it, especially while running.

When we first examined the pragmatic and hedonic experiences displayed in Table 2, the frequency value of the codes showed that the pragmatic experiences of the users were higher than the hedonic experiences for both products. This result shows that users can express their pragmatic experiences more easily when conveying their experiences. The majority of the codes created under pragmatic experiences were clustered under the wearability experiences rather than the other categories. The fact that users made a lot of positive and negative comments about wearability experiences also justified the importance of comparing different wearing styles of textile-based and accessory-based wearable technology products.

In Table 2, the frequency values are created to compare users' experience of the accessory-based wearable technology (chest band) and textile-based wearable technology (T-shirt) products. These frequency values showed that textile-based wearable technologies lead to more positive experiences overall, as shown in Figure 5 (abbreviations are shown in Table 2). In terms of wearability, the T-shirt had more positive experiences than the chest band. The T-shirt has more positive experiences in terms of fit (W1), mobility (W4), sensory adaptation (gradual decrease over time in the responsiveness of the sensory system to a constant stimulus) (W6), and thermal comfort (W5) compared to the chest band. Participants reported 21 positive experiences for the fit of the T-shirts during the process, compared to only 3 for the chest band. For thermal comfort, the frequency value of the T-shirt was 14, while the chest band was 1. When we compared the negative experiences, the chest band fit frequency value was 30 and the T-shirt fit frequency value was 11. While the negative sensory adoption chest band frequency value was 12, no negative experience was reported for the T-shirt. The most important reasons for this were that the chest band loosened and moved on the body, or squeezed the body and caused more sweat when worn tight. Users commented on this situation as "I think it is designed to be a nuisance because it feels like someone is hugging me from behind" or "It was uncomfortable because the chest band made me sweat more". The chest band, on the other hand, had advantages in terms of doffing and donning, because the T-shirt completely wrapped the body, causing difficulties for the users, especially when taking it off ("On the first day, it was difficult to put on and take off, although the product fit my size. I got help from my wife in removing it"). It is noteworthy that the chest band had the highest frequency of negative experiences in terms of tactile comfort (W3). While the participants did not express negative tactile comfort for the T-shirt, they stated 21 negative experiences for the chest band. Although this result is related to the material of the product, it shows that the product is not fully suitable for user mobility. Since the two products use similar technologies, there were no significant differences in usability, only users expressed negative experiences about the connection (Ub2) problems of the T-shirt. The reason for this was related to the applications installed on the phones. The T-shirt provided positive experiences, especially in terms of providing motivation (Uf1) and increasing performance (Uf2). While users did not have a negative experience with the T-shirt in terms of motivation and performance, there were negative experiences with the chest band. Users stated that their performance decreased ("It did not increase my performance, on the contrary, I restricted myself in case it fell off") due to wearability problems such as fit and mobility of the chest band.

Comparing the visual aesthetics, there was no significant difference in the frequency values between the T-shirt and the chest band, but both products led to negative experiences in terms of size/form (V1) (frequency chest band = 10, frequency T-shirt = 12). The most important reason for this was that users did not want the technological parts of these products to be visible ("If the device was a little smaller, it would look more stylish and hi-tech"). It could be seen that the T-shirt had more positive experiences in visual experiences such as color, high quality appearance and good looking. The frequency value of positive experiences for good looking for the chest band was 12, and the frequency value of the T-shirt was 14. These results also showed that the users liked the products visually. Due to the fact that the chest band is worn under the clothes, users generally did not care about the visual aesthetics of the chest band. This situation also affected the social experiences. ("Since

it is in direct contact with the skin, other people do not see it. This is a disadvantage"). Users had more interaction with their friends and social experience (S1) because the T-shirt was more visible. In terms of emotions, it was seen that the T-shirt had more positive experiences than the chest band. It can be concluded that users had more positive feelings for the T-shirt, that the T-shirt was more liked by users and would be used longer than the chest band ("I felt happier, more active, better, more secure while wearing the T-shirt compared to the chest band") (Positive S1 f cb = 9, f T = 19; Positive E1 f cb = 4, f T = 14).

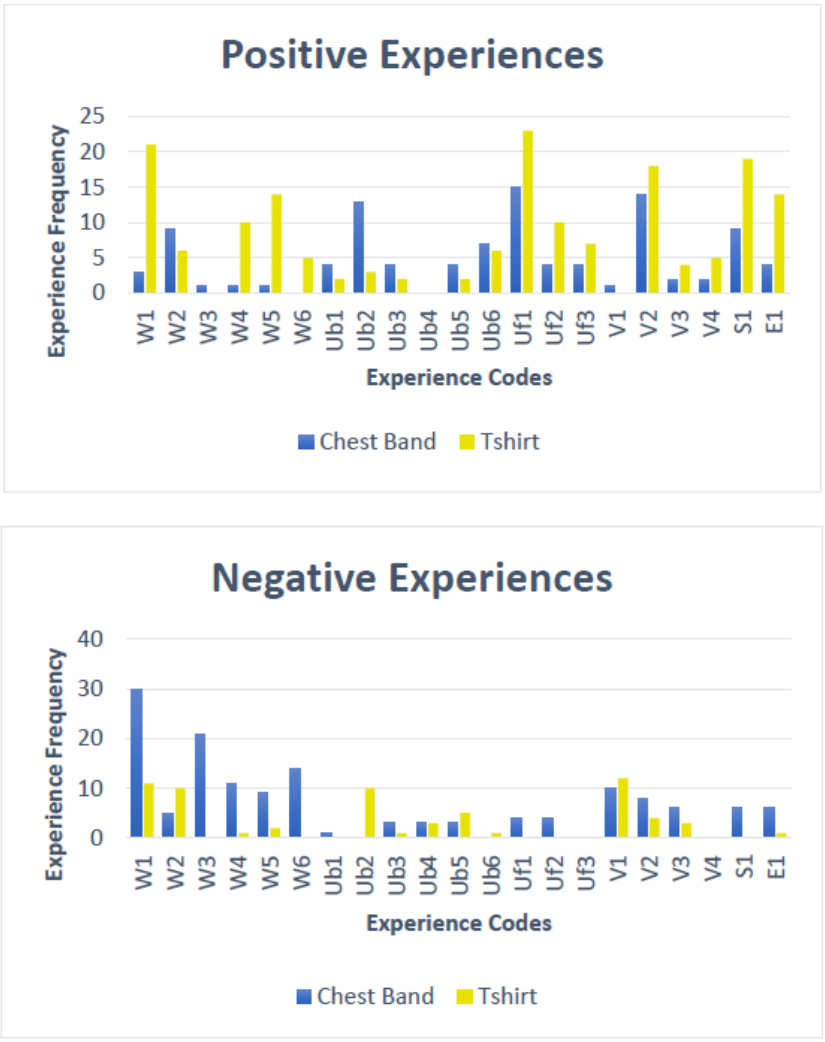


Figure 5. Comparison of positive and negative experiences between the accessory-based wearable chest band and textile-based wearable T-Shirt.

The comparison of the pragmatic and hedonic experiences of the users, depending on the form and movements of the body, is of great importance in terms of the design of wearable technology products. It was determined that the smart T-shirt had a lot of positive experiences against the chest band in terms of fit, mobility, thermal comfort, positive emotions, and social experiences. In terms of negative experiences, there were wearability problems such as the chest band's tactile comfort, and lack of sensory adaptation. Although comparisons were made on products designed for the chest area in our study, this situation may differ for other parts of the body. As Fernández-Caramés & Fraga-Lamas [24] said, when wearable technologies are foreseen to be implanted in our body in the future, it is normal for wearable technologies to be integrated into clothing today. In this study, we concluded that wearable technologies integrated into textiles and clothing created a more positive user experience instead of wearing them directly on our body as an accessory.

Karapanos et al. [65] stated that the degree of perception regarding positive and negative user experiences is critical throughout the product life cycle from use to disposal and repurchase. For this reason, it is important to investigate what the positive and negative experiences of wearable technology products are and how they change over time. When we examined the user experience as a process in wearable technology products, it was observed that there were more positive experiences than negative experiences during the use phase as represented by Figure 6 (abbreviations are shown in Table 2). As a result of the high number of positive experiences, it could be said that the expectations of the users were met throughout the usage period, and they were satisfied with the use of the product (during use total positive experiences = 150, during use total negative experiences = 107).

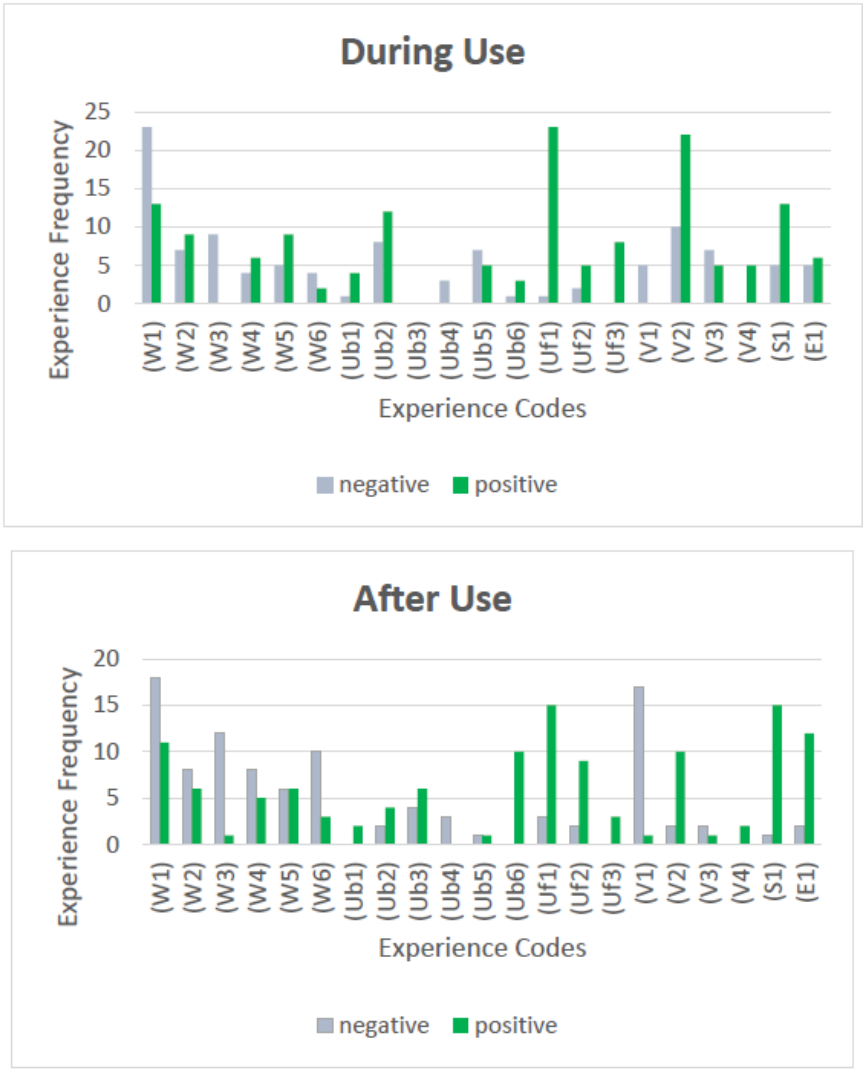


Figure 6. Positive and negative experiences during use and after use.

If we consider the pragmatic experiences categorically, while the negative experiences were noticeable in the wearability category during use, it could be seen that they increased even more after use. While the negative experience frequency value during use for the wearability category of the participants was 49, this value became 61 after use. In particular, negative experiences about sensory adoption (W6) and mobility (W4) increased at the end of the use process. This could mean that the product discomfort restricted the movements of the user during exercise. In terms of usability experiences, it was determined that negative experiences decreased at the end of the use phase. It is noteworthy is that users' connection (Ub2) and data exchange (Ub5) experiences decreased over time both negatively and

positively (during use > after use; f Ub2 = 20 > 6, f Ub5 = 12 > 2). Users followed a certain order and process to connect wearable technology products to their smart phone. Especially, after users had solved the connection problem and learned how to use the product, data exchange and connection disappeared from the users' attention. This time, the accuracy (Ub6) of the data gained importance. This shows the importance of examining the user experience over a period of time as displayed in this study. When usefulness was examined, it was seen that user motivation (Uf1) decreased, and performance (Uf2) increased over time (during use > after use; f Uf1 = 24 > 19, f Uf2 = 7 > 11). With the excitement of using a new product, it is normal for the motivation to be high at the beginning and during-use phase and to decline over time as excitement diminishes. Users having positive thoughts about their performance also showed that wearable technology products that track activity were beneficial, especially for athletes and those who exercise regularly.

When we examined hedonic experiences categorically, in the visual aesthetic experiences, the number of negative experiences of users about the size/form (V1) of the products had increased from 5 to 17, over time. The frequency of experiences about color (V2) and looking good (V3) had declined over time both positively and negatively (during use > after use; f V2 = 32 > 12, f V3 = 12 > 3). According to this result, it could be concluded that users got used to the color and aesthetic appearance over time, but the negative experiences increased due to the relationship between the size/form of the products and wearability and fit issues. Finally, when the social experiences and emotion categories were examined, only positive emotional experiences increased over time. While the frequency value of the positive emotional experiences of the users was 6 during use, it increased to 12 after use. The positive emotions of the users showed that they were satisfied with the use of the wearable technology products. In the post-use interviews, many users stated that they especially wanted to use the smart T-shirt later.

Since the emotional state is constantly changing over time and emotions have a subjective nature, it is more difficult for users to convey hedonic experiences than pragmatic experiences [66]. Accordingly, in our study, pragmatic experiences such as wearability, usability, and usefulness, especially conveyed by users, were more than the hedonic experiences such as visual aesthetics, social experiences, and emotions. Gemperle et al. [67] emphasizes the active relationship between the physical form of wearable technologies and the human form. Similarly, in our study, the users especially shared their positive and negative experiences the most in terms of the wearability. This shows us how important wearability is for the design of wearable technologies.

The positive experiences of users on motivation also drew attention. In order for the motivation to be high, a product should be easy to use; a product with low usability may decrease motivation [68]. Parallel to this, the high motivation of users in our study can be explained by the fact that positive experiences on usability were more than the negative ones. Finally, in the evaluation of positive and negative experiences, users had both positive and negative experiences about the aesthetic appearance of the products. This shows us that users give importance to product visuality as much as usability and wearability. Despite the fact that the visual aesthetic value was the lowest in the survey study in which we measured the user expectations, the evaluations of the users during the use of the product and after the use process showed that the aesthetic value of the products was important in terms of design.

The temporal aspect of user experience is an important research topic, but has been neglected [69]. This study shows the changes in the user experiences during and after use of two wearable technology products. While the positive experiences of the users decreased over time, their negative experiences did not change much. Positive user experiences that have drastically declined over time were usability (connection), visual aesthetics and usefulness (motivation). This correlates with the findings of Karapanos [70] that the user experience develops and changes over time; although learnability, innovation and beauty are very important at the beginning, after long-term use, they will not motivate as much as other aspects.

Finally, when we analyzed the negative and positive experiences of the participants according to gender differences, there were no remarkable differences (Figure 7). In negative experiences, while men had negative experiences with the fit (W1; f woman = 16, f man = 25) of the products, women had more negative experiences with the form (V1; f w = 16, f m = 6) of the products. In positive experiences, men reported more positive experiences than women on the thermal comfort (W5; f w = 2, f m = 13) and good looks (V2; f w = 10, f m = 22) of the products. As a result, considering the products experienced in this study, no significant role of gender was detected in the comparison of experience of textile-based and accessory-based wearable technologies.

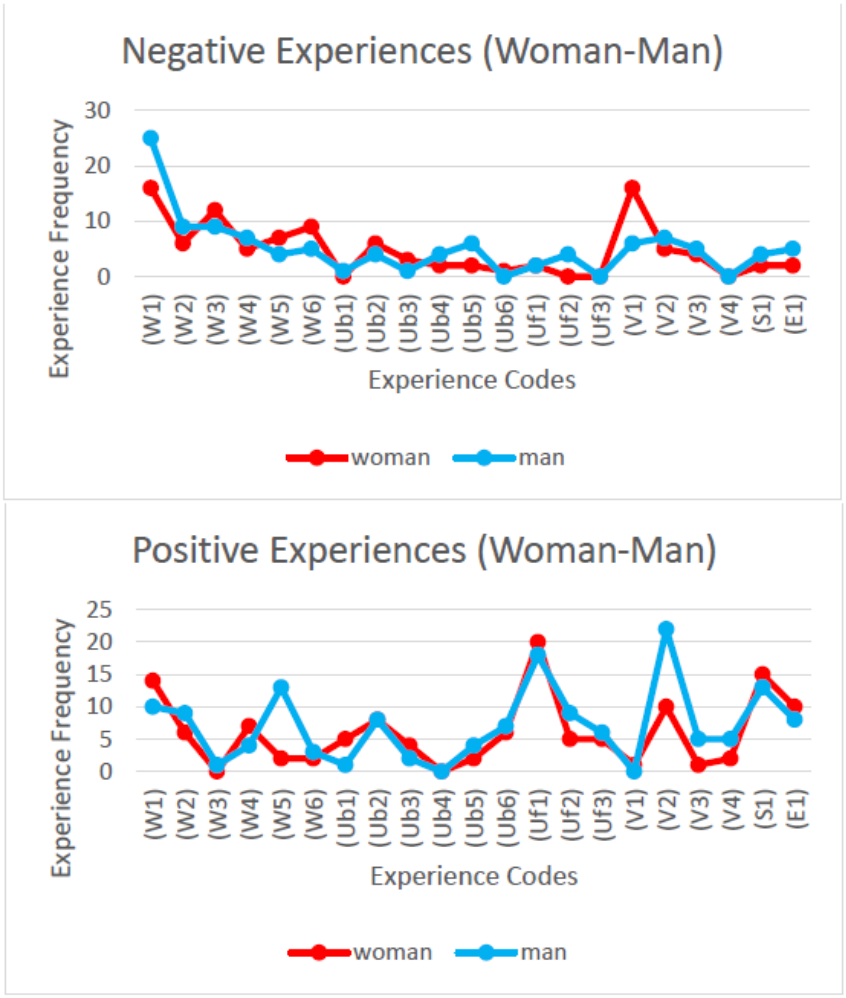


Figure 7. Comparison of positive and negative experiences by gender.

4. Conclusions

This study examined how user experience in accessory-based and textile-based wearable technologies changes over time and presented this change as users' positive and negative experiences from the pragmatic and hedonic perspectives in a comparative manner. The study yielded new insights into the user experience that product and fashion designers can use while designing wearable technology products.

The users' expectations and experiences are important in terms of facilitating the adaptation process of wearable technologies and reducing product abandonment rates. In this user-experience research, comparing two different products with different wearing styles revealed that a textile-based wearable technology product had much better wearability, usefulness, social, emotional, and visual aesthetic experiences. In terms of wearability, textile-based wearable technology had more positive experiences regarding fit, mobility,

sensory adaptation, and thermal comfort compared to accessory-based. For this reason, we can say that textile-based fitness wearables provide more motivation and performance to users. It is concluded that textile-based wearable technologies designed as clothing could create more positive experiences and be adopted by users for a longer time.

The study also presented a new mixed method in user-experience research. First, a survey was conducted to learn about the expectations of the users. Afterward, the diary-interview method was employed in order to learn the daily experiences of the users over the two-week period. A semi-structured follow-up interview was conducted to understand the experiences of the users after the use of the product. This multi-phase method developed to compare the user experience of two different wearable technology products with the same function was tested and is promising for future studies. In future work, this method can be used as a template and can be tested with different products and more users.

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